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A PUBLIC HEALTH APPROACH TO EVALUATING

THE SIGNIFICANCE OF AIR IONS

By

STEPHEN M. KINNE, BS, MD

APPROVED:

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Benjamin Bradshaw, Ph.D.

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Frank Moore, Ph.D.

# DEDICATION

To my wife of twenty years, Ann, who is both my anchor and my greatest source of love and happiness. To my kids, Carrie-Ann and Jeremy who have given me a sense of pride I never thought possible. To my parents, Jane and Charlie, who have always encouraged and supported me. And lastly, to the Air Force which, although having taken me away from my family on many occasions, has provided me with an wealth of diverse opportunities while allowing me the privilege and honor of serving my country.

In a less formal way, I would also like to dedicate this project to all those people I have met along the way who have convinced me that it's never productive to close one's mind to any idea, even if it doesn't fit one's particular frame of thinking at that time (this was not always an easy lesson to learn). No matter how sophisticated we believe we have become, there is much we do not know and considerably more we do not yet understand. Although we will probably always strive for complete understanding and mastery of the natural world, based on detailed scientific discovery and evolving technology, I suspect that nature's complexity will outwit us every time. Maybe more important than the understanding of every detail of nature is just the understanding of where we fit into it.

# A PUBLIC HEALTH APPROACH TO EVALUATING THE SIGNIFICANCE OF AIR IONS

By

STEPHEN M. KINNE, BS, MD

Thesis

Presented to the Faculty of the University of Texas

Health Science Center at Houston

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF PUBLIC HEALTH

THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON
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Submitted: April 18, 1997

A PUBLIC HEALTH APPROACH TO EVALUATING

THE SIGNIFICANCE OF AIR IONS

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School of Public Health, 1997

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For greater than sixty years, controversy has surrounded the topic of air ions and their possible effects (both beneficial and adverse) on humans. Although many of the early studies were criticized for being flawed and results were frequently conflicting, the preponderance of them seemed to be in agreement that atmospheric (air) ions were at least *active* in biological systems. However, cause-effect relationships for human conditions or diseases were less conclusive and often contradictory. Unsubstantiated medical claims for ion generating devices and concern over ozone byproducts by from these machines led to the imposition of harsh marketing restrictions by the FDA in the early 1960's. As a result, serious interest in air ion research declined and has remained at relatively low levels in most scientific circles. Over the years, the technology and study designs have improved, but inconsistencies in findings have persisted. Despite this, a growing number of ion generating devices are being purchased, the sales undoubtedly influenced by fairly regular reports in the popular press about the health benefits of negative ions. Much of the scientific work in this field and the socioeconomic factors at work in the marketplace are unknown to most practicing health

care providers. Yet, many will be asked to give professional opinions or advice on the use of these devices for various health reasons. This paper will explore air ions from the standpoint of a classic Public Health dilemma, and will present and use an epidemiological approach for judging a possible cause-effect relation-ship between air ions and health effects. A fairly inclusive bibliography is also offered as a resource for those wanting to explore particular aspects of the field in more depth.

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# SECTION I

# INTRODUCTION

## Statement of Purpose

Air ions, charged atoms or molecules naturally existing in minute concentrations in the air we breathe, have been studied and reported on for nearly a century. Claims for their effects on everything from mood and alertness to asthma and allergies have been made. Ion generating devices for both personal and industrial use are commercially available and the market appears to be growing. Yet, the majority of people in this country (and especially medical professionals), seem to know very little about these air ions or the commercial devices designed to produce them.

The initial purpose of this thesis paper was to answer two simple, straightforward questions: (1) Is there a *biological* effect of air ions as claimed and, (2) if so, does this effect translate to any *health effects* on humans? Unfortunately, there is no simple, straightforward answer for these questions. In fact, as one goes deeper into the existing literature and begins the journey through scientific disciplines such as biometeorology, bioelectromagnetics, geo-physics, etc., in addition to the "traditional" biomedical disciplines, a story of increasing complexity emerges. Simply put, there is a great deal that science has already uncovered in this area of study, but a tremendous amount that we do not yet know or understand. Inter-mingled with this science-related knowledge base are some fascinating bits of history and politics which have tangibly affected both the reputation and credibility of the field, along

with some equally pertinent sociological factors that have also influenced how the field is perceived.

This account illustrates a fairly classic public health dilemma, not at all unique to the question of air ionization. It involves evaluation based on incomplete, inconsistent, or conflicting data and the consequent lack of a scientific consensus, and involves eventual decisions influenced by public concerns, politics, and economic (market) forces. The first part essentially necessitates the construction of a risk analysis model (the "risk", in this case, being the alteration of normal ion levels by man-made activities and structures). The remainder of the process then involves the merging of this risk characterization with those aspects of sociology, public perception, economics, and politics to devise a risk management policy. In the end, of course, this risk management process must be accompanied by communication to those individuals or groups potentially affected. This project may represent part of this latter effort.

The thrust of this paper, therefore, will <u>not</u> simply be another critical review of the scientific literature. Several of these have been done in the past, including one book devoted entirely to that end. Admittedly, that "most recent" review was published nearly fifteen years ago. A survey of pertinent studies involving one particular facet of the field will be incorporated into the paper, but this will not represent the totality of the project's goal. Also recognize that the paper is not written in a "typically scientific" manner because it is not directed exclusively at scientists. It is also not a popular journalistic piece on the author's opinions of air ions. Instead, it is aimed at presenting facts, ideas, and theories related to the possible significance of air ions as we understand them today so that the reader may come to

his/her own inferences and conclusions. Ultimately, information from this thesis paper might be utilized to construct a more formal review article suitable for submission to a general medical journal.

To summarize, the goals of this thesis project are:

1. To analyze the air ions issue as a classic example of a public health dilemma.

2. To provide sufficient overview of the field of air ion study for a reader to be able to better interpret the continued flow of both scientific and popular information on the subject.

3. To use an epidemiological approach to look specifically at a possible cause-effect relationship between air ions and behavioral and/or neuropsychological changes.

4. To strengthen the ability of the reader to make decisions concerning appropriate advice and/or recommendations for patients and the general public on the use of ion generating devices.

5. To provide a fairly comprehensive, current bibliography as a reference point for those interested in carrying out more detailed analyses of individual reports.

6. To consider future directions for this field of study.

## Design of the Paper

Section II will present a historical overview which is valuable in putting the present state of air ion research and knowledge into perspective. It will also show how the field has been continually influenced by science, politics, and economics during that time. As part of the historical review, a listing of the many claims made for air ionization will be presented. Lastly, a more scientifically oriented discussion on air ion composition and terminology will

be undertaken along with a description of some of the difficulties encountered in studying these substances.

Section III will define an approach to be used in this paper to evaluate a portion of the extensive literature on this subject (well over 1,000 papers have been published along with numerous unpublished graduate theses, scientific texts and lay books). Most of the scientific literature on human effects has consisted of interventional laboratory or clinical experiments, usually with relatively small samples . There have been no large scale epidemiological studies, with the possible exception of those few dealing with increased health problems, crime, and accidents occurring concurrently with certain "ill winds" (such as the Foehn, Sharav, and Santa Ana). Despite the lack of epidemiological studies, an established method used by epidemiologists to assess possible cause-effect relationships represents a potentially valuable tool in categorizing and evaluating such a large group of scientific studies. Therefore, the remainder of section III will involve application of this epidemiological tool to one specific aspect of air ion research.

The final summary in section IV will discuss the information presented and weigh the evidence for or against a cause-effect relationship between air ion alteration and significant biological effect. Section V discusses the air cleaning sector of commerce, and those related products (and their claims) presently on the market. Lastly, in section VI, conclusions and comments on potential future directions for the field of air ion study will be addressed.

## SECTION II

## BACKGROUND AND HISTORY

### Indoor Air Quality

In order to put air ions into a more familiar context initially, it would be valuable to first discuss the larger issue of air quality, and indoor air quality in particular. This makes sense if one accepts the premise that air ions, if they are biologically active and significant, are likely to exert their effects through the medium of air, and are primarily a problem with indoors environments. This preliminary discussion is, therefore, important in setting the stage for later sections which deal specifically with air ions.

Air quality has long been recognized as a public health issue. It can conveniently be thought of in terms of two major categories: macro-environmental and micro-environmental. Traditionally, the term air pollution has referred fairly exclusively to the contamination of outdoors air (thus, *macro*-environmental). Although indoor air pollution has been known to effect health ever since man brought fires inside dwellings, efforts to control air pollution have been focused outdoors. It was logical that outdoor air would receive the most attention since, fouled by industry and other man-made inventions, it looked and smelled bad and produced acute effects such as burning eyes, cough, and sneezing. But the physically irritating aspects of polluted air were not the only things that led to public concern and action. According to David Lord, Professor of Architecture at California State Polytechnic University, there are deeply ingrained cultural beliefs that have to be factored in. He writes:

> During the latter part of the 18th century, the concept of miasmata as a cause of disease, that is to say, the dangers from bad odors, and the theory of

> the importance of decaying vegetable and animal matter in the causation of illness became widely accepted.
>
> To this day, the fear of air as a cause of illness is general in Western culture and in Middle America.[104]

The Clean Air Act and its amendments were passed here in the US in response to these concerns about the quality of the outside air. Since its passage, great strides have been made in reducing macro-environmental air contamination.

In the past two decades, however, there has been increasing recognition of, and concern about, the air quality found in indoor microclimates (i.e. micro-environmental).[139] Indoor air quality (IAQ) issues, ranging from formaldehyde off-gassing to Sick Building Syndrome (SBS) and aircraft cabin air quality have been thrust to the forefront of public attention and concern. Concern over cancer, infectious disease, allergy and irritation have all been ascribed to indoor air pollution. A wide range of allergens, pathogens, irritants and organic chemicals have been implicated in such air quality concerns. These issues are particularly important since they involve a wide range of micro-environments, from workplaces to enclosed transportation modes (cars, airplanes, etc.) to private residences. Unfortunately, consulting engineers and industrial hygienists often discount the clinical aspects of indoor air quality and may not attempt understanding of the complex nature of occupant complaints.[21] The Occupational Health and Safety Administration (OSHA), going against their traditional industrial work site orientation, has recently become involved in non-industrial work sites primarily because of such IAQ issues and problems. The Federal Aviation Administration (FAA) is currently looking at aircraft cabin air quality and legislation has been proposed in Congress. No agency, however, oversees air quality and safety in the

home or in private conveyances. This may be primarily due to the cost of such an huge undertaking, but it is also greatly influenced by the negative reaction towards any type of governmental intrusion into private homes or possessions.

The key question, of course, is whether all this concern over IAQ is even justified? It may well be, considering recent estimates that American's spend up to 90% of their time in indoor environments. This figure is staggering, implying that many people spend virtually their entire lives indoors (most likely the very young and the very old who are also the most susceptible to toxins and contaminants). There exists an expectation that indoor air provide a comfortable environment (i.e. compared to outside) with the absence of unpleasant odor or irritation.[87] However , airborne contaminant levels (especially of volatile organic compounds or VOC's) in man-made structures may well exceed those considered unsafe in the outdoor air. The problem is that many of these indoor contaminants are not readily perceptible. Our drive for energy efficiency and economy (occurring primarily as a consequence of the oil embargo in the late 1970's) may have exacerbated the IAQ problem. In an effort to reduce heat loss and the associated higher costs, buildings were "tightened" and ventilation rates were reduced. The consequence of these actions may well have been to allow these indoor contaminants to accumulate at even higher levels. Therefore, the potential public health aspects of IAQ are enormous, and may touch the lives of virtually every American. Air ions, in turn, have been *implicated* by a number of investigators as being significant determinants of comfort, and possibly health, in indoor environments. Thus, one must question whether their unintentional alteration, a common occurrence in the indoor environment, might actually constitute a threat to public health.

## Air Ions

As will be further detailed in the historical overview section, there has been interest in air ions throughout this century, and the debate on biological effects and potential health effects continues. Interest in air ionization initially began after case studies of patients affected by changing levels of air ions. As more became known, interest also came from a number of other areas. According to Slote, interest in air ionization was also stimulated through nuclear weapons testing, nuclear power generation, cosmic radiation (encountered in space flight), with the use of high voltage/high frequency electrical equipment in closed or confined spaces, with air pollution, and with air conditioning and hot air heating.[136] Additional interest has come from the electric power industry when it was discovered that high voltage direct current (DC) power lines produce plumes of air ions from transformers which can reach ground level and which also can be dispersed some distance depending on prevailing winds.[26,75] Lastly, although work is largely secret, it is likely that "directed energy" research (including that encompassing directed energy weapons) involves work with air ionization.

Air ion depletion or imbalance has been implicated in a variety of ailments, many of them similar in characteristics to those seen in SBS, etc.[21,62,98] With this in mind, one may wonder if there could be a connection between air ion depletion or imbalance and health complaints arising from indoor micro-environments. In fact, it has been demonstrated that man-made structures frequently behave as large Faraday cages, essentially insulating occupants from naturally occurring electrical or ion-producing phenomena.[90, 136] Artificial air conditioning and heating also markedly deplete the ion levels of incoming air. Electrically

charged surfaces (such as video display screens, synthetic carpeting and clothing, etc.) further attract and deplete ions. Pollutants ranging from tobacco smoke to volatile organic compounds (VOC's) can significantly reduce the ion levels.[7, 20] Essentially, we have constructed indoor micro-environments with the potential for them to be nearly devoid of the natural and normal electrical space charge. It would therefore be logical to question whether many of the vague complaints characteristic of conditions such as SBS could be explained, at least in part, by a depletion or imbalance of natural air ion levels. Having seen the potential health implications of poor indoor air quality and having considered the fact that disruption of normal air ion levels occurs as a matter of routine in indoor air environments, one might also wonder if anything is being done to compensate for these depleted air ion environments and, if so, has a benefit been observed for the occupants. Future sections of this paper will begin to explore these questions.

In the meanwhile, however, many people concerned over these IAQ issues, have turned to mechanical air cleaning devices to help rid their homes, offices, cars, etc. of the many possible contaminants that have been reported. Because of this, the popularity and sales of various air cleaning devices (categorized as either air cleaners, air purifiers, and/or air ionizers) continues to grow. This growth is not a new phenomenon. Sales of air cleaning devices have followed an oscillating course since back in the 1950's. The present upsurge is considered by some to represent the "fourth wave" of popularity.[79] These waves tend to follow both consumer concern as new information arises, as well as the advent of new devices as technology evolves. Despite the technological improvements, however, disparities between industry claims, anecdotal patient reports, and scientific studies have continued.

With the proliferation of these devices and with their thinly-veiled claims for improving health conditions (including allergies, asthma, fatigue, symptoms of sick building syndrome, etc.) it is important that health professionals be aware of these devices, understand how and why they are supposed to do what they are claimed to do, what scientific backing exists to support or refute the claims made, and what laws regulate their marketing and sale. Only then can health professionals adequately do the following:

1. ***give advice*** to patients who will come seeking information on these devices (since manufacturers' advertisements virtually always recommend that patients discuss use of these products with a health care provider),

2. decide whether these devices may be suitable to use ***therapeutically*** in certain select patients, and...

3. ***make recommendations*** on the use of these devices on a larger scale such as in multi-person offices, industrial work sites, residential buildings, or even public conveyances (e.g. commercial airliners). It is in this last regard that public health officials need to sufficiently understand the field. If it has already been established that indoor air quality is one of the biggest public health issues facing us in the foreseeable future, one needs to know if air ions are a significant part of the problem.

## Historical Overview

> If one were to search deliberately for a long-tenured controversy, he could not do better than to choose the question, 'Are small air ions biologically active?'
>
> Krueger 1976

Atmospheric electricity was "officially" discovered in the late 1700's by Benjamin Franklin although records indicate several other scientists who did work with the same phenomenon. In the late 1800's it was confirmed that air electricity actually depended on the presence of electrically charged molecules found naturally in the air. Much work was done in the first part of this century on the properties and effects of these air ions. However, 1932 is generally recognized as the year when real interest in this country in the biological effects of air ions began. The often told story of Dr. Clarence Hansell, working at RCA laboratories in Princeton, NJ, details how he noted distinct and reproducible mood changes in a coworker whenever that person remained in the vicinity of a particular electrical generator. Upon investigation, this generator was found to be emitting high concentrations of positively charged air ions. Significant interest was thereby generated in the possible biological effects of air ions and enthusiastic investigations commenced. Note that during these early years some of the most prolific air ion research was done in countries outside the US, particularly in the Soviet Union.[79, 83, 95, 138, 159]

The onset of WW II largely put ion research on hold, especially here in the US. There was one unconfirmed report of the German Luftwaffe using negative ion generators in their aircraft to decrease pilot fatigue, but little other mention of air ions during this time.[138,158] After the war ended, two major events influenced this field of research greatly. First, due to

the rapid evolution of technology that occurred as a result the war effort, scientists, now armed with a much advanced array of scientific instruments, began to view most of the pre-WW II studies as invalid because of the "technologically inferior" methods and equipment used in those investigations. Consequently, much of the previous work was given little further recognition. Second, because of the Cold War which developed with the Soviets, research from that country was either not shared with the outside scientific community or, if it became available (especially here in the US), was largely ignored by the scientific community.

In the mid-1950's work was accomplished which delineated some of the biological processes thought to be involved with air ion action (e.g. serotonin mediation). Interest in air ions increased significantly, largely spurred on by manufacturers of artificial ionizers who claimed all manner of cures for various medical problems. In the early 1960's, the Food and Drug Administration's (FDA's) Bureau of Medical Devices became involved due to the "unsubstantiated" medical claims (i.e. lack of good scientific backing) and also because of concerns about ozone by-products from these devices. The FDA subsequently promulgated regulations which banned the advertising and sale of these devices for medical purposes. That action largely stymied bona-fide researchers in the field. Research funds all but dried up by 1970, both because of the field's "bad name" and because of the lack of commercial incentives for sponsoring such studies.

In the late 70's and early 80's, a third resurgence in interest for artificial ionizers occurred in response to concerns about indoor air quality. Science magazine, October 1980, contained an article entitled "Ion Generators: Old Fad, New Fashion" and talked about the

reincarnation of the devices with "a different sales pitch that stops just short of claiming any medical benefit." [144] Although the article was written in a surprisingly unscientific and biased manner, the author did site sources which showed that sales that year were expected to reach $10 million. Despite the growth in air cleaner sales, however, the continued lack of consistent, widespread scientific backing and the continued restrictions by the FDA kept the use of these devices from becoming too widespread.

Now, in the 1990's, the "fourth wave" of interest appears to have arrived, aided by the mass media and the advent of computer marketing via the Internet. Again, this interest still stems largely from continuing concerns about indoor air quality. Concern also appears to be caused by reports of the increasing incidence and severity of asthma, and also because of growing awareness (and fear?) of medical conditions such as Multiple Chemical Sensitivity (MCS), Chronic Fatigue Syndrome (CFS), etc. Public knowledge about air ions has come almost exclusively from popular press reports. Articles on the beneficial health effects of negative ions have appeared in publications such as Reader's Digest, Psychology Today[38], Allure, Backpacker[5], and Muscle and Fitness[169,170] magazines. At the time of this writing, the San Antonio city newspaper is running a series by their meteorologist concerning weather, air ions and their effects on people, and how one can purchase an artificial ion generator to improve health and a sense of well-being. Air ionizers have also been featured on major TV network news shows including NBC World News and CBS Evening News. Not surprisingly, capsule coverage reporting like these fails to present a complete and balanced review of pro's and con's of this complex, highly controversial subject. Only the "newsworthy" aspect tends to be presented. Yet, the mere presence of articles and reports like these in such a variety of

informational forums generates public interest, contributes to a impression of validity in the reports, and probably heightens concern in some. In addition to the above-mentioned articles and reports, advertisements for air ionizers and related devices can also be found in numerous lay health and alternative medicine publications, as well as in company-sponsored booths at home improvement fairs, etc. As alluded to earlier, manufacturers also have expanding access to homes via the Internet, where a multitude of sites extol the virtues of air ions and discuss how their company's product(s) can benefit the consumer. As a consequence of all these factors, artificial ionizers constitute a continually growing line of goods. The FDA still does not allow them to be marketed for the treatment of specific health (i.e. medical) conditions, but they can be advertised and sold as air cleaners or air purifiers. Despite the written regulations, however, medical claims are regularly being made, or certainly implied, by the manufacturers.

## Claims

There are a number of aspects of air ionization that make it both intriguing and equally frustrating. One such aspect involves the type of research done on the subject. Unlike many potential disease processes which begin with a case report (or series), progress to epidemiological studies to investigate the distribution and determinants of frequency of this condition in the population, and follow up with investigational trials (if warranted) to both confirm findings and delineate the basic science of the disease, air ionization largely skipped the middle step. The discovery of air ions in the early part of the century led researchers to look for possible effects in biological organisms (a finding looking for a disease). Some

effects were eventually found, often inadvertently. But, without a true disease, there were no population-based epidemiological studies performed. Instead, limited experimental trials were performed with relatively small samples of human subjects (often without adequate controlling of variables). This, in turn, resulted in claims for health benefits and to the consequent boom in artificial ionizer sales. Over the subsequent four decades, more than a thousand reports have been published on air ions (according to the American Institute of Biomedical Climatology), but most have continued to be fairly small investigational trials or case series reports. Unfortunately, the continued lack of consistency in design and control of variables in many of the studies along with the variety of organisms, species, and strains used in the studies, and combined with the varying endpoints aimed for (or arrived at) all have made the task of looking for valid trends quite difficult. It is a small wonder that inconsistent and oftentimes contradicting results have been the rule.

In sifting through the literature from the 1930's to the 1990's, one is able to compile a general list of claims that have been made for both negatively and positively charged ion species. Since negative ion generators are the devices almost exclusively being sold to the general public (negative ions have almost uniformly been related to beneficial effects, while positive ions normally are associated with adverse effects), a list of purported benefits from negative ions will be presented below. Note that this list is undoubtedly not all-inclusive and the scientific validity of each claim will not be individually explored. Instead, this unreferenced list is meant to give the reader an idea of the *extent* of the claims, and to serve as a starting point for further researching should one's interest be piqued. The following

effects/claims, listed in no particular order, have been associated with artificial negative ionization of the air:

1. improvement of asthma
2. improvement of allergies (only while on ionized environment)
3. improvement or resolution of migraine headache
4. cessation of pain from burns, with early formation of eschars, decreased odor, and reduced post-burn infection rates.
5. decreased post-operative pain (general surgical)
6. improvement of arthralgias, joint inflammation, and rheumatoid joint disease
7. improvement of psychiatric conditions (e.g. bipolar disorder)
8. improved performance on vigilance tasks
9. decreased fatigue, increased alertness, increased energy
10. improvement in mountain (altitude) sickness
11. increased tracheal ciliary action
12. improved peptic ulcer disease symptoms and increased healing of ulceration
13. increased weight loss in obese patients
14. increased exercise (work) capacity
15. augmentation of therapy for CO poisoning
16. reduced BP in hypertensive patients
17. decreased cancer cell growth
18. reduced bacterial, viral, and fungal growth (bactericidal activity in many cases)
19. improved learning

20. increased resistance to carbon monoxide, cooling, ionizing radiation, and infections in pressurized cabin atmospheres

21. reduced reaction time, (visual, auditory)

22. increased oxygen carrying capacity of blood

23. decreased perceived exertion at maximum load levels (bicycle exercise testing)

24. decreased headaches, nausea, dizziness, and complaint rates in office workers

25. decreased infection rates in office buildings

26. positive changes in mood (e.g. increase relaxation, increased sense of well-being)

27. improved sleep in normal and "neurotic" patients

28. reduced hemoptysis, expectoration, and fever in tuberculosis patients

29. eradication of pertussis (whooping cough) symptoms

30. reduction/eradication of epileptic seizures (idiopathic and Jacksonian types)

31. decreased dizziness, anxiety

32. eradication of choreoform movements and speech dysfunction in a Chorea patient

33. marked improvement in Seasonal Affective Disorder (SAD)

As noted again in later sections, the incredible range of effects on this list, demonstrating a notable lack in specificity, induces a strong skepticism for the overall plausibility of the air ion field. Yet, despite this initial reaction, one should not completely rule out the possibility of multiple, non-specific effects. This would be especially true if the target system(s), such as the hormonal and/or central nervous system, were to govern the activities and functions of many different aspects of the organism.

## Air Ion Composition and Terminology

In order to fully appreciate the discussion on air ions one must have some grasp on the concept of air ions, where they come from (i.e. how they are formed), how they are depleted or destroyed, and how they may potentially interact with biological systems. First and foremost, air ions are charged clusters of atoms or molecules (positively or negatively charged) existing in the ambient atmosphere. Ions are not new and they are not solely the product of human invention. Rather, they exist normally in nature, produced primarily by the action of cosmic and solar (UV) radiation, radiation from radioactive material in the earth (primarily radon and thoron), and atmospheric lightning on molecular constituents of air. They also may be produced from frictional or sheer forces on water or sand (e.g. from waterfalls or during sandstorms). There are a number of man-made sources of air ions, including ionizing radiation equipment, high voltage direct current (DC) power lines, cathode ray devices, and commercially available artificial ion generators. The key feature of all of these is the presence of sufficient energy to affect separation of atoms or molecules with consequent loss or gain of an electron (thus, production of an ion).

The exact identification of air ions remains debated but one can imagine that there could be a wide range of them depending on the gaseous constituents of the air. The composition of ions could also be significantly altered by the presence of pollutants and contaminants in the air. The primary air components of $N_2$, $O_2$, $CO_2$, and $H_2O$ probably form the main substrates for most of the ion formation but others certainly have been theorized or implicated.[39, 40, 61, 64, 123] It is also likely that many air ions consist of more than one constituent. Most commonly, these would be additional attached water molecules. This multiple

constituency composition would be especially true with the medium-sized and large air ions. The relative lack of knowledge and/or agreement about the composition of air ion species is important from the scientific standpoint as there has been little work to demonstrate which of these species might actually be active.

Another notable and important feature of air ions is their size. There are three general classes of ions; small (mobile), intermediate, and large (immobile). Mobility refers to the ion's velocity measured within a standard electric field. As one can readily deduce from their definition, the size and mobility characteristics are inversely related. Consequently, size (i.e. mobility) becomes an additional factor along with chemical make-up when evaluating study results for possible effects. At present, almost everyone writing in the field of air ionization seems to accept that the small, mobile ions are the ones of significance to biological organisms.[39, 85] The exact reason for this belief is unclear, however, as no studies were found which specifically analyzed the different ion types for biological activity. In any case, when conducting investigations it would be important to characterize and report what size/mobility ions were being produced.

In additional to polarity, chemical composition, and size/mobility the actual amounts (i.e. concentrations) of air ions must be taken into account when evaluating for a possible effect. The natural, outdoors levels for (total) small air ion concentration is reported to fluctuate continuously, but ranges from about 500 ions per $cm^3$ to as high as 12,000 ions per $cm^3$.[22, 30, 35, 81, 85, 88, 90, 133,145] Climate, weather, altitude, geography and geology all have an impact on prevailing levels. Most reports tend to fix the "normal" range at about 800-3,000 ions/$cm^3$. A typical clear day in a rural area not at altitude is often estimated to have 2,000

ions/cm$^3$. It is important to know these values as natural ion levels can both fall to negligible amounts under certain conditions (e.g. indoor atmospheres with crowding, tobacco smoke, electric fields, etc.) and yet can reach levels far above normal under other conditions (e.g. with artificial ionizers used either for therapy, or in "clean rooms").[22, 175] Thus, accurate measurements of the level(s) of ions present and the amount actually reaching the subjects are of prime importance in attempting to establish the presence of an effect and a dose-response relationship.

To put air ion levels into further perspective, one must also recognize that the actual concentrations of ions compared to non-ionized air molecules is extremely small. This dilution factor, even in artificially-induced "high ion" atmospheres, may result in only one ion for every $1x10^{14-16}$ non-ionized molecules. Clearly, with this low a concentration, a typical chemical reaction would be unlikely, if not impossible, to explain any effects noted. Therefore, one must consider other mechanisms for possible action (e.g. such as the ions acting as a biological signal, subsequently amplified by the organism to produce an effect).

Lastly, the ratio of positive to negative ions could well be important and must be considered. Although actual air ion concentrations may fluctuate widely, the normal ratio of slightly greater than 50:50 (positive ions: negative ions) is usually preserved. If the normal ratio were to be disrupted, however, an effect could be exerted. However, such an effect could exist only if there also existed a sensitive enough receptor in the organism to perceive such a change.

Armed with this background, one must now be aware that there are numerous factors which have been reported to alter the levels of ions in the air. Almost all aerosols (solid and

liquid states that exist in the atmosphere) will diminish ion levels through random collision and charge transfer. This fact demonstrates the importance of considering factors such as air pollution and humidity. The presence of electrostatically charged surfaces can also have a significant influence on ambient levels by "extracting" ions of opposite charge (i.e. through attraction and contact neutralization). Many examples of the latter can be found in the present indoors environment and include air conditioning ducts, carpeting, synthetic clothing and furnishings, video display and television screens, etc. Additionally, a human (or animal) has the ability to accumulate a significant electrostatic surface charge, especially if in contact with synthetic materials while being insulated from ground. Most people have directly experienced this surface charge phenomenon, usually after walking across a carpeted floor when the air is dry and then "getting a shock" upon touching a surface. This sparking represents the transfer of charge from the body to a grounded or oppositely-charged object. The importance of all this is to realize that, depending on the polarity of a surface charge accumulated on a subject's body, air ions can either be attracted to or repelled by the subject.

All of these factors are important to know because they all need to be considered when designing a scientific experiment. One can imagine the potential difficulty in setting up such an experiment where it is necessary to control for type of air ions (including species, charge, and size), accurately measure concentrations of each, control for air contaminants (including those possibly produced by the ion generation itself), eliminate all extraneous electrical or electromagnetic fields and electrostatic surfaces (including consideration of clothing materials, subject grounding , etc.), and control physical parameters (e.g. temp-erature, humidity, lighting, and air conditioning). A daunting task to be sure, especially when

dealing with human subjects. But, in fact, not controlling for all of these many variables is exactly what has made most of the air ion studies easy targets for criticism in terms of their validity. Consider, however, that even if one was to devise the "perfect" experiment and was able to isolate one single variable to test, one would have to ask if it would be valid or meaningful to carry out such a test since such a condition would never to expected to occur in nature? Could the actual effect have been due to interactions between various components of the complex atmosphere that have just been removed? Or, if an effect was demonstrated, would that effect normally have been overshadowed by other simultaneous effects and thus have no real relevance in and of itself?

Then, in addition to these considerations for controlling variables, one must lastly look to the validity of extrapolating data from animal models to humans. To sum up all these factors, Hennekens writes that "While basic animal and laboratory research can achieve virtually complete control of exposure, environment, and sometimes even genetics, their results may differ so greatly from those that apply to people as to render them of no direct relevance to humans".[66] Thus, the reviewer must recognize and accept the fact that few human studies related to air ions will be able to conform to such ideal and rigid scientific standards in design. Studies may, therefore, have to be appreciated for and judged by their relative conformity to good design principles and their clinical applicability.

Now that basic terms have been defined and discussed, and consideration has been given to the immense complexities in trying to design experiments, one must next take into account the specific nature of the biological organism being studied. As alluded to above, care certainly must be exercised in extrapolating information from bacteria, insects or plants

to mammals, and from any of these to humans. Even with human experiments, care must still be taken in extrapolating results from a few individuals to an entire population consisting of innumerable individuals and potentially having diverse sub-populations with varying degrees of susceptibilities.

Once all of these considerations are made, the final step is to actually settle on a methodology to consistently study the effects on the organism. Unfortunately, in humans this must often be non-invasive, indirect, and/or designed for subjective responses. Consequently, interpretation of results is often fraught with difficulty and possible bias. All of these factors must be considered as one evaluates and analyzes the existing literature and reports such as this one.

## SECTION III

## AN APPROACH TO EVALUATING THE DATA

### Epidemiological Approach to Cause-Effect Relationships

It would be ideal if there was a scoring mechanism for study data where a simple summation could be used to validate or reject a particular hypothesis, process, or cause-effect relationship. Unfortunately, there is no such mechanism. However, rather than merely render a superficial reporting on each of several hundred scientific reports, letting the reader somehow tabulate the individual plusses and minuses with the hope of coming to an objective answer, a different tool will be employed here. It was pointed out in the introduction that no population-based epidemiological studies have been carried out in this field. The possible exception to this might be those investigations describing certain meteorologically unique "ill" winds found in different areas of the world. [Examples of these winds are the Foehn in Europe, the Sharav and Scirocco in the Middle East, and the Santa Ana wind in southern California. These warm, dry winds have been described by several investigators as being preceded (from hours to days) by altered concentrations and ratios of air ions, the latter significantly favoring positive ions.[128,142,143] An association between the arrival of these winds and an increase in motor vehicle and work accidents, crime, suicides, homicides, and hospital admissions has all been reported.[116, 128] This is fascinating reading for those interested in biometeorology, but it is too extensive a topic to be included in this paper.] However, the discipline of epidemiology does offer a methodological tool that could be used to classify the

existing studies and aid in the judgment concerning causality.[66] It is based on the presence of seven positive criteria that are briefly described below.

1. Strength of Association - The greater the magnitude of the increased (or decreased) effect observed, the less likely the relationship is due to chance or confounding variables.

2. Biologic Credibility - If there is a known or postulated biologic mechanism by which an exposure could reasonably produce the effect observed, than belief in a cause-effect relationship is heightened. The obvious limitation here would be the current state of knowledge. Note that the lack of a known or postulated mechanism does not mean that a relationship does not exist, and therefore also does not mean that a relationship is not a causal one.

3. Consistency with other Investigations - If a number of investigations, all done in the same manner, consistently show a similar event-outcome relationship, then belief in the existence of a true relationship would be enhanced. Consider, however, that under uniform conditions, a single confounding variable could be present in all of them, thereby causing all results to be in error. Therefore, probably even more compelling evidence might be the presence of similar results determined from many studies conducted by different investigators using different methodologies and done at various locations, times and cultural settings, etc. It would be unlikely that the same relationship would occur in all by chance alone. One must be careful however, not to discard seemingly "inconsistent data" obtained from such a non-uniform group, as a trend in susceptible sub-populations could be missed. Note that a common source of criticism from other scientists often involves the "different methodologies" concept mentioned above. It is usually fairly easy to find fault in most methodologies and

justify discarding this non-uniform data, rather than to recognize the inherent limitations but still look for similar, overarching trends in all of the investigations. The other factor that might be included in this category is the absolute numbers of investigations. As an example, if three studies are done, two being positive and one being negative, this means that two thirds of the results are "consistently" positive. However, a reviewer would not likely come to this conclusion since it is based upon a two-thirds positivity of a very small number. But, if 1,000 studies were performed, and two-thirds of these were positive, it would be hard to ignore the sheer number of positive results even though one-third of them were still not consistent. This also goes along with the concept of "the weight of the evidence". When studies are inconsistent or conflicting, it becomes particularly important to search out the best designed and executed ones and confer more importance or weight to them.

4. Temporal Relationship (Time Sequence) - Simply stated, an exposure needs to precede an outcome or effect in order for it to be causal. If the exposure does precede the outcome, the time period between exposure and outcome should also be consistent with whatever biologic mechanism is known or proposed.

5. Dose-Response Relationship - If a gradient of exposure results in an associated gradient of effect, belief in a causal relationship would be strengthened. This by no means proves a cause-effect relationship and, conversely, the absence of a dose-response does not negate the possibility of a cause-effect relationship. Also, one must be aware of the possibility of a "window" of effect or a threshold phenomena when interpreting gradients of response.

6. Specificity - If an exposure consistently produces a specific outcome or effect, belief in a cause-effect relationship increases. An exposure which reportedly produces a variety of non-specific effects or outcomes must be viewed with great caution, if not suspicion. At the same time, if the exposure variable acts though multiple biologic processes (directly, or indirectly through another system) it is certainly possible that a wide range of effects could occur.

7. Coherence - Given the present state of knowledge and understanding, one must ask if the observed relationship coherent (i.e. does it make sense). Again, as with biologic plausibility, the danger is that the present state of knowledge may be inadequate to allow a coherent explanation or rationalization. For this reason an open mind should always be kept in order to incorporate new ideas, knowledge and understanding as they unfold.

The next seven sections will look at each of these categories with respect to one particular aspect of the air ion field of study, pointing out how various investigational studies either do or don't support it. In the follow-on summary, presence or absence of a cause-effect relationship will be discussed based on the strength of these seven categories.

## Air Ions and Neuropsychological/Behavioral Changes

In section II, a lengthy list of claims for negative air ionization was presented to give the reader an idea of the scope of this topic. It would be impossible in a paper such as this to fully explore each of the actual studies for their scientific and statistical validity. However, emerging from the reviewed literature as one of the most consistently reported effects associated with exposure to altered levels of air ions, is that involving neuropsychological

and/or behavioral changes. In fact, the preponderance of studies published since about 1980 have been involved in looking at this very topic. This paper will therefore limit its scope to scientific reports which look at both the direct, physical effects of air ions on the central nervous system and on observed neuropsychological and/or behavioral changes.

1. Biologic Plausibility. One might first ask whether air electricity (space charge) *should* have any effect on a biological organism. We tend to forget that there is, in fact, a great deal of electrical activity going on continuously within the body (witness EKG and EEG as examples of "external markers"). Varga writes, "The life process is an extremely complex process in which physical and chemical phenomena are closely interwoven, manifesting themselves as the biological process".[157] With a pertinent association established, one must next explore origins of resistance to belief in one. One component that initially makes many scientists skeptical of this field is the lack of a defined biologic mechanism of action (especially after nearly seven decades of study). Although skepticism is a healthy attribute, it should not prohibit access to belief. History is replete with examples of scientific ideas that were initially scorned, only to be proven true years, decades, or even centuries later. It has been written of the general scientific community in the US that the characteristic initial response to a new idea is to decry it as ridiculous or impossible. Only if the concept survives long enough to be proven beyond a shadow of a doubt by a number of perfectly designed, incontrovertible scientific studies does the possibility of its actual existence become acknowledged.[138] Although perhaps a bit overstated, it is largely accurate that our science culture does demand proof of existence before acceptance. Although this "rigidity" may stifle some

creative, "outside-the-box" thinking, it does serve to protect society (to some degree) against shams, charlatans, and unscrupulous entrepreneurs.

Proof of effect and proof of mechanism of action, furthermore, do not always evolve at the same time or rate. For example, there are a number of drugs in today's sophisticated medical arsenal where the mechanism of action is not entirely understood, but they are used regardless, because they have been proven to work. The procedure of acupuncture, used for centuries in the Far East, is now accepted as a viable therapy for a wide variety of conditions. Yet, proof for the mechanism of action, despite many theories, also remains elusive.

An additional item which helps to defy belief in the existence of a plausible mechanism of action for air ions is the number and range of physiological and behavioral effects ascribed to them. Section II listed over thirty reported effects from negative air ions alone. Although this will be touched upon again in the section dealing with "specificity", it is also germane to this discussion. In essence, the possibility of finding a believable, rational mechanism of action for a *single* outcome following a defined exposure is certainly much greater than finding a similarly believable mechanism that could explain *several dozen* different outcomes from the same single exposure variable, as is the case here.

To explore biologically plausible explanations for air ion action, one must first know how they "enter" the organism. Amongst scientist who have studied the biological effects of air ions on mammals, one thing seems to be largely agreed upon, and that is that the primary route of exposure and location for ion effect is the respiratory tract. Of those who ascribe to this route of entry, it is also a nearly unanimous feeling that the location of ion "deposition" is probably in the lower respiratory tract, prior to alveolarization. The only other theory, which

may or may not be complementary, relates to external surface (skin) exposure. There are some very interesting observations about changes in skin electrical potential with air ion alterations and at least one hypothesis draws parallels between their possible mode of action and that of acupuncture.[103] The thought is that the air ions, known to be able to change the skin's electrical potential, may also be able to induce minute currents at acupuncture points and produce their internal effects by similar, albeit unknown, mechanisms.[103]

Beyond a general agreement on the likely site of entry via the respiratory tree, agreement on a specific receptor and/or an actual mechanism of action remains a topic of much discussion. The key for this discussion is to find a mechanism that will ultimately tie in to the CNS so as to be capable of bringing about psychological or behavioral changes. The most widely recognized of the theories, based on quite a number of past scientific studies and anecdotal stories, involves a linkage between air ions and the neurohormone serotonin (5HT or 5-hydroxytryptamine). Serotonin is a very potent and versatile chemical which can exert profound neurovascular, endocrine, and metabolic effects throughout the body.[10, 11, 40, 46, 54, 61, 74, 112, 158] It constricts smooth muscle in airways, blood vessels, and in the gut. It also can stimulate afferent nerve endings and cause platelet aggregation. Lastly, it is concerned with the transmission of nerve impulses in the central nervous system (CNS). In this latter regard, 5HT occurs in substantial quantity in the lower midbrain where it plays a vital role in certain basic life patterns such as sleep and emotion. Serotonin is broken down by the monoamine oxidase (MAO) enzyme system which prevents it from accumulating.

Dr. Albert Krueger, working at the Berkeley Air Ion Lab in the late 1950's and 1960's, was the first in this country to postulate this serotonin connection after observing

certain changes in mammalian tracheas upon exposure to positive air ions.[89, 95] These positive ion-induced mucosal changes included congestion, erythema, and markedly reduced ciliary function. The abnormalities were completely reversed by exposing the tracheal specimens to negative air ions. Because it was recognized that these initially-observed changes clearly resembled those induced by injecting serotonin intravenously, Krueger also tried injecting reserpine (an MAO inhibitor and serotonin antagonist). Reserpine was, in fact, able to block the effect of the positive ions just as the negative ions had done. Measurements of whole blood samples taken after positive ion exposure also demonstrated decreases in platelet serotonin levels, and an increase in serotonin metabolic products in the urine was also found. Thus, it was hypothesized that positive air ions somehow increased serotonin release from platelets, possibly through inhibition of the monoamine oxidase enzyme system, while negative ions opposed this by accelerating the enzymatic oxidation of serotonin. It was felt that serotonin, widely recognized for causing a variety of neurovegetative changes, could be the sought-after link between ion level changes and the many-described effects on the organism. Although Krueger's work is still frequently quoted, there have been others who have criticized the design (especially the lack of control of temperature, humidity, and air quality) and the interpretations.[11, 12] Even Krueger, himself, conceded at a later time that the results may have involved the combined effects of other environmental factors along with the air ions.[90]

It was further pointed out that many of the serotonergically-related ailments and conditions (e.g. migraine and depression) were characterized by similar symptomotology to those attributed to altered air ion levels. Further work was then done by Sulman and others

which also implicated serotonin as the mediator for biological effects. Sulman has probably been the next biggest proponent of this theory, doing most of his work in Israel while studying the adverse health effects of the Sharav winds. Sulman's studies have been criticized for their lack of controls, insufficient presentation of data, lack of statistical analysis, etc., and therefore are considered inconclusive by many scientist's criteria.[11, 12, 174] However, he repeatedly recorded two things. First, according to his measurements (and reported earlier by others, also), the Sharav winds were preceded by an increase in both positive air ion levels and a positve:negative ion ratio. Second, he could affect a reversal of patient's Sharav-related symptoms by treating them with either negative air ions or MAO inhibitors (serotonin antagonists). He also noted increased levels of serotonin metabolites in the urine of these patients, all suggesting 5HT involvement in what he termed the "serotonin irritation syndrome".[142, 143]

Additional studies reporting a reduction in serotonin following exposure to negative air ionization came from Krueger and Kotaka (1969), Gilbert (1973) and Diamond (1980). Krueger's group found that the brain content of free serotonin in rats was responsive to air ions, just as peripheral levels had been in previous investigations. They noted these effects in as little as twelve hours, with return to normal after 24 to 48 hours, and then decreasing again by 72 hours. (The rise at twelve hours was postulated to be due to some sort of homeostatic feedback mechanism with the organism attempting to compensate).[93] Some researchers note that the method of brain tissue preservation and analysis was faulty, however, and could have distorted the results. Gilbert demonstrated that continuous negative ion treatment of stressed rats significantly decreased their emotionality (adverse response to handling) but also showed

a concomitant decrease in brain serotonin levels.[55] Retrospective critical review by Bailey argued that appropriate statistical analysis actually demonstrated a lack of significant effect from ionization.[11] Diamond demonstrated that long-term exposure of rats to negative air ions (three months) led to an increase in cortical weight in both the somatosensory and occipital areas of the brains. He also noted a significant decrease in both serotonin and cAMP levels in these same areas.[37] Bailey and Charry performed a very well designed and controlled investigation in 1987 which demonstrated no effects at all of air ions or electric fields on serotonin.[8] More recently, Dowdall carried out experiments with rats exposed to negative and positive air ions. She found a definite difference in the responsiveness of pyramidal neurons to serotonin, with negative ions increasing and positive ions decreasing this response. Interestingly, she found no significant differences in the whole brain or plasma concentrations of serotonin or its metabolite.[40]

Three additional studies of air ions which might add to the discernment of a mechanism of action were performed by Morton, et al, studying learning tasks in mentally retarded children. Although the study variables and results are complex, the outcome was that negative air ions definitely showed an effect best described as a general, non-specific increase in the cerebral arousal level.[112-114] The mechanism of this effect was not established although serotonin was implicated. An absolutely fascinating case series, reported by Misiaszuk, looked at negative ionization effects on a small group of bipolar disorder patients in the manic phase. There was a dramatic calming effect on these patients with negative ion exposure, many of them falling asleep within fifteen minutes of beginning treatment (some having to be physically awakened to complete the evaluation). This effect disappeared within

15-30 minutes of discontinuing the negative ion treatment. Although no blood or urine testing was done for serotonin (or its metabolic by-products), it was theorized that this effect was also due to ion-induced decrease in brain serotonin.[111] Of the studies described above, several only *postulated* a serotonin mechanism of action. Only the rodent studies by Krueger and Kotaka, Diamond, Gilbert, Bailey, and Dowdall and the human studies by Sulman (working with an uncontrolled meteorological phenomenon) actually involved objective measurements of serotonin. So, despite nearly four decades of thought that serotonin was likely associated in the action of air ions, this remains unproved. Recent investigations have shed further doubt on the likelihood of a primary role, but the issue remains unresolved.

Another theory that came about primarily to explain the inhibitory or lethal effects of negative ionization on bacteria and fungi involves the formation of superoxide radicals from ionized oxygen.[76, 132] Although this is fascinating in its own regard, there have been no proposed or coherent theories on how superoxides could be involved in the production of neuropsychological or behavioral effects.

So far we have dealt with only proposed biochemical theories of action. Kellogg consolidated various hypotheses into three main theories relating to the potential biologic mechanism of air ions. The first was the chemical theory which would include the serotonin hypothesis just discussed. The biggest flaw or criticism with this theory with respect to air ions involves the minuscule concentrations of them in the air. He, and others, expressed the opinion that a typical chemical reaction was highly unlikely because of these minute levels.[11,75, 80, 88, 145] He further postulated that the ions must stimulate some sort of specific receptor(s) and that the signal would then be amplified within the organism (possibly

involving a hormone such as serotonin at this level). He likened this type of amplified mechanism to that seen with pheromones, where minute quantities are sufficient to cause an effect. There are other examples in the animal kingdom of receptors which are exquisitely sensitive to certain stimuli. One example in humans is the perception by the retina of a single photon of light.[75, 90] No such ultra-sensitive receptors are yet known for air ions. However, Kavet builds an excellent case for certain neuroendocrine cells (NEC's), found in the mucosa of the lower respiratory system, being the potential receptor. He postulates that these "amine precursor uptake and decarboxylation" (APUD) cells, occurring either solitarily or in clusters, might well act as pulmonary chemoreceptors. The clustered cells, potentially acting like other receptor nodes such as carotid body sensors, also appear to be located in conjunction with afferent and efferent nerve terminals, mostly originating from the Vagus nerve. Secretory products of these neuroendocrine cells, which include serotonin and dopamine, might thus act as neurotransmitters in addition to other local actions. Stimulation of these pulmonary NEC's by inhaled air ions could possibly result in release of serotonin both locally (through secretion) as well as in the central nervous system via the afferent neural connections.[74] Thus, both peripheral and central effects could be seen. This is an important concept since it is recognized that the two systems function independently, despite using the same neuro-hormone substrate (i.e. serotonin does not traverse the blood-brain barrier).

Kellog's second (electrical) theory primarily deals with direct current-dependent effects.[75] It has been demonstrated by investigators in other fields such as bioelectromagnetics that there is a direct current (DC) control system intrinsic to biologic organisms. This control system seems to play an important part in growth and regeneration processes. Air

ions have been shown to cause minute DC electric currents to flow in a grounded subject, although the exact internal and/or external pathways are not known. It is possible that disruption of the intrinsic system by these induced currents could have effects on the organism. This theory might be consistent with the hypothesis advanced by Lipinski, who postulated that piezoelectric phenomena could represent the similar mechanisms of action for acupuncture, manual manipulation, air ions, and Hatha yoga.[103] Piezoelectricity is a phenomenon involving the appearance of electrical charges when a particular substance, such as a crystal or an organic polymer, is subjected to a mechanical strain. Structural elements of the body composed of piezoelectric substances may be capable of transducing mechanical energy into an electrical current. As mentioned previously, it has been postulated that external-to-internal pathways of air ion currents may correspond to the acupuncture points on the meridian charts. Air ions could directly stimulate these electrical receptor sites on the skin surface, inducing a flow of electrons into the body. Unlike acupuncture, however, ions would be expected to be more nonspecific in their effect since their action is more random. Obviously, much more investigational work would be needed in the area of bioelectrics to determine if these mechanisms are, in fact, present and whether they may be linked at all to air ions action.[75]

The last item put forth by Kellog relates to the theory of indirect action of air ions through electrostatic precipitation of airborne contaminants. Electrostatic precipitation is a process that is accepted by virtually everyone (see section V on air cleaners). It has been unequivocally demonstrated that if you can impart a charge to airborne particles you can "precipitate" them out of the air. There are two general methods for accomplishing this. The

first involves pulling particulate-containing air into a device which attaches a charge to the particles as they pass through an electric field. The charged particles are then attracted to opposite-charged electric plates as they exit the device. These devices are used in homes, businesses (especially where cigarette smoking is allowed), closed space environments such as submarines, and clean rooms where dust particles could adversely affect silicone chips, etc.[42, 175] The second mechanism is by an ion generator which blows ions into the air where they attach themselves to suspended particles. These charged particles are then attracted to opposite-charged surfaces such as walls, etc.[86] The human effect theory is that there are also many airborne allergens (pollens, molds, insect feces, etc.), bacterial pathogens, and non-specific irritants which can cause a variety of symptoms in susceptible people. Removing these contaminants would, therefore, be expected to improve such people's condition. There is some evidence for this, although inconsistent, in studies involving negative ion treatment with allergy suffers and some asthma patients.[3, 4, 18, 33, 60, 71, 84, 115, 119, 120, 124, 125, 159 164-5] It has even been suggested that this electrostatic precipitation process could entirely explain some of the "bactericidal" effects noted on earlier studies.[85, 91, 108] Here, air ions could attach to and charge aerosolized bacteria which then preferentially precipitate out onto walls, etc. instead of settling out and growing on the culture media dishes.

However, despite this well-described and accepted process, electrostatic precipitation does not account for the variety of biochemical, physiologic, and psychomotor effects noted in many studies. It also would not explain the *different* effects of negative and positive ions. Kellog also points out that the recognized necessity for grounding experimental subjects[26, 49]

would also not be valid if electrostatic precipitation was the only process at work. Clearly, this may represent a piece of the whole picture, but it fails to explain the effects entirely.

At this time, the lack of a defined mechanism of action remains a major stumbling block in the acceptance of this field of study by the general scientific community. However, it would appear that there are several possible bioelectrochemical theories which exist that, although not proven, might be considered plausible based on our present state of knowledge.

2. Specificity. In the historical overview of this paper, a section was devoted to the variety of claims (over thirty) made for negative air ionization over the years. Obviously, therefore, it would be hard to make any general claim of specificity for their effect. If one were to look at the study titles, however, one would quickly deduce that the majority have concerned themselves with behavioral and neuropsychological effects, and with effects on the respiratory system. There are two other general trends in "specificity" that can also be noted. First, the preponderance of data available suggests that it specifically is the small, mobile air ions that have the predominant effect on biologic systems, particularly human (although, as mentioned previously, the evidence for this belief is unclear). Second, the preponderance of data also suggests that it is specifically the negative ions that tend to produce beneficial effects, whereas positive ions are associated with adverse effects. Several human studies have been performed which showed no adverse effects from short term exposure to negative air ion concentrations.[141] (The only study which noted any adverse effects of negative ions at all was one utilizing and evaluating rats who lived their entire lives in ionized chambers. Rats existing continuously in environments with high concentrations of negative ions had a shorter

survival time than the others. It was theorized that chronically accelerated metabolism may have actually shortened their life expectancy.[78])

In terms of specificity, therefore, the effects that have been described are numerous and not specific to a particular organ or system or outcome. The majority have dealt with neuropsychological/ behavioral and respiratory effects, however. It is largely accepted that it is specifically the small, mobile air ions which exert an effect on biological systems, and that there is a relatively specific beneficial effect to negative ions compared to an adverse effect to positive ions.

3. Coherence. The question of whether or not a finding or theory "makes sense" is often a difficult one to answer. What seems reasonable to one person may be pure lunacy to another. An interesting passage in an article by Igho Kornbleuh quoted another scientist (identified only as O'Neill) as saying "Almost all novel projects in science pass through the lunatic fringe before being incorporated into the orthodox nucleus but, of course, the mortality in making this transition as very high".[83] History has shown that this transition may take years, decades or even longer.

Getting back to the question, does this while field make sense? To address coherence one should first look to the process of evolution. During the millennia, organisms have been exposed to a great variety of harmful agents as well as beneficial (health restoring) ones. Any environmental elements present continuously or periodically are likely to be incorporated in some way into the organism's processes during its evolution. Basic geophysics tell us that all biological organism, including the human race, evolved in a sea of electromagnetic influences,

including ionized air. The evolution and development in such an environment invites the supposition that nature may well have utilized air ions in developing certain biological processes, just as it has for so many other physical and chemical agents. Varga writes "...electrical factors had an effect on the origin in life. The environmental milieu of the organism shows quite definite electrical properties, and metabolic processes are linked with ion exchange within the body."[157]

Early Russian experiments by Tchijevsky and reported by Krueger[90] showed that animals kept in air deprived of essentially all ions eventually became sick or even died. If accurate (and this author could not find any repeat studies to verify this), it would certainly answer the fundamental question of whether air ions are essential for life. Krueger also reported on work done by Kimura in 1939, who studied the effect of indoor air lacking in small ions. He found complaints of depression and perspiration even though $CO_2$, temperature, and humidity were all kept constant. Symptoms were promptly relieved when negative ions were supplied. Again, the suggestion is that the absence of ions may be detrimental (thus, the presence is essential).

The environment we now live in is certainly much different than the one existing at the time of our distant ancestors. Man evolved in, existed in, and adapted to relatively clean, pure air where levels of naturally occurring air ions would be expected to be relatively high. The pollution we encounter today and our increasing dependence on man-made, insulated structures significantly alters the air, including its electrical properties. Additionally, our ancestors lived, literally, with their feet on the ground, thus being "grounded" electrically. Air electricity could therefore use a body as a electrical conduit. In contrast, modern man is

typically insulated from the ground due to footwear and contact with synthetic or man-made floor coverings. A large build-up of surface charge of one polarity or the other can consequently occur, acting to either repel or attract air ions in close proximity to the body.

Assuming our systems evolved to confront and adapt to the majority of conditions in the environment found at an earlier geologic time, then a concern would be that they might not have developed the feedback systems necessary to meet all the conditions rapidly imposed upon ourselves in today's modern life.[74, 157]

Two major arguments would be advanced concerning air ions and their potential effect on organisms based on these evolutionary ideas. First, the concentrations of air ions are extremely small… many scientists say too small to have an effect on such a large and complex organism as a human (i.e. the "dilution" argument).[12, 88] Second, there are continuous fluctuations in "normal" ambient air ion levels depending on weather conditions, time of day, location, and a variety of other factors, so why would exposure to artificially-generated levels be of any consequence (i.e. would it not be just one additional variation)?

There are two responses to these very valid points. First, if ions were, in fact, to exert influence on a complex biological organism, then it is likely that they would act as a biologic signal, catalyst or even hormone instead of a typical chemical reactant. There are systems in nature where this type of phenomenon happens. Response of insects and crustaceans to minute concentrations of pheromones or electromagnetic fields, or the recognition of a single quantum of light by a human retina are examples of the biological responsiveness to extremely small stimuli. So, it is possible. Second, as for the variations, many physical and chemical influences have shown periodic, sometimes marked variations during our

evolution (e.g. temperature, humidity, geomagnetic fields, etc.). The living organism must, and does, adapt quite readily to these changes in order to maintain its internal homeostasis and biologic processes. If the organism fails to adapt or if the variation becomes marked and prolonged so as to disturb the internal equilibrium, then the result is stress.[157] This may eventually manifest itself in sickness or even death. In essence, fluctuations may be the norm, whereas sustained elevations, depressions or imbalances may signal that something is wrong.

Another point to be made concerns individual variation in susceptibility to the effects of stimuli. Science readily recognizes and accepts the concept of a "normal" or bell-shaped distribution curve for a wide variety of responses, behaviors, etc. Is it not conceivable, therefore, that only a proportion of individuals in the population might be significantly affected by more subtle changes in air ion levels (i.e. ones that would be minimally noticed or imperceptible to the great majority)? It is interesting to note that it has been estimated that approximately 25% of the population is sensitive to air ion changes[142, 143], about 25-30% of the population is "weather sensitive", [68, 142] and a positive symptom rate (both reported and unreported) in sick building investigations is about 30%. [87] There have been inadequate studies to find out if there is disproportional overlap in these three areas which might imply a common link or similar process at work.

Therefore, from an evolutionary standpoint and taking into consideration our present understanding of levels of biological responsiveness, the concept of individuals responding to minute levels of environmental stimuli is coherent. The idea that individuals may vary in their susceptibility or responsiveness to that stimuli is also coherent. Consequently, the notion that

air ions might be able to influence a complex biologic organism to varying degrees is within the realms of possibility.

Having looked at evolution, let us turn to another observation that may lead one to infer that air ions may have biological activity. For years, especially in Europe and the Soviet Union, it was recognized that certain locations seemed more conducive to health and restoration of the body. In fact, many health spas were located in such areas. Subsequent monitoring in these areas revealed higher than expected levels of air ions, usually due to increased radioactive rock strata in the area (a common source of naturally-occurring air ions).[22] Armed with this knowledge and with the fact that people for centuries have gone to natural uranium springs for their healing properties, scientists have taken measurements of air ions in these radioactive springs areas. Again, air ion counts are significantly higher in these locations. There are even thoughts that certain "power spots" or "sacred areas" of the earth, known for centuries to native populations, also tend to be high in air ions and/or strong electromagnetic fields.[5] Although not proven scientifically, these intriguing observations also suggest that complex organisms, including ourselves, could be "in tune" with minute electrical influences not consciously perceived.

4. Consistency of Investigations. Of all the sub-topics in the air ionization field, probably none has been quite as controversial and contradictory as that of the neuropsychological and behavioral effects of air ions. There is considerable anecdotal evidence and a strong perception amongst the public and some scientists that negative ions make one feel

better or more alert, while positive ions tend to do the opposite. Certainly, the advertising for negative ion generators imply a *uniformly beneficial* effect to all people using them.

An even more basic and less qualitative question to answer, however, is do air ions actually exert *any* true effect on the central nervous system? If an effect is definitely able to be demonstrated, then the next steps would be to determine any patterns or trends in those effects (e.g. alteration in mood, behavior, state of alertness, etc.). The basic scientists would then also be involved in determining the mechanism by which such minute quantities of charged particles could exert their effect on a system as complex as the CNS. To answer the first *quantitative* question (i.e. is there any true effect on the CNS?), the following chronologically presented information from the past four decades of scientific study is offered.

Starting in 1957, Silverman and Kornbleuh reported significant EEG changes (decreased alpha wave frequency) with exposure to either positive or negative air ions.[135] In 1959, Jordan and Sokoloff found that negative ionization significantly decreased the number of errors and maze-time scores of older rats (previously had 2-3 times greater errors and time scores than young rats).[72] Similar maze results were found by Duffee and Koontz in 1965.[41] In 1960 and 1962, Chiles looked at complex mental tasks in 60 university students under varying ion conditions (high/low, and negative/positive) for several hours. He found no significant changes in performance of tasks or vigilance in either study.[29, 30] In 1964, Barron reported no noticeable improvement in a small group of healthy, rested, quiet airline pilots on certain cognitive performance tasks.[16] In 1966, Nefedov from the Soviet Union Space Biology Program studied males subjected to extended stays in a pressurized cabin (twenty days). In addition to stating that "all (Soviet) researchers recognize that air ions influence the

function of the CNS", he specifically noted increased subjective feelings of well being and reported EEG changes (intensification of excitatory processes) with negative ionization. Positive ions had the opposite effect. [118] That same year, Wofford tested undergraduate psychology students performing research tasks under different ion conditions. Negative ionization had a significant effect by improving reaction time but had no effect on measures of manipulative dexterity.[167] In 1967, McDonald reported increased mental performance for both negative and positive ions.[105] Also in 1967, and in several subsequent studies, Frey reported on the relative anxiolytic action of negative ions on rats (observed in rats with induced anxiety states).[48] In 1969, Terry and Hardem noted that male rats studied showed significantly lower error scores while in negatively ionized air. They postulated that this effect was due to modification of the level of vigilance.[149] In 1969, Krueger and Kotaka published additional animal studies which demonstrated a decrease in brain levels of serotonin after mice received ion exposure (positive and negative).[93]

Gilbert, reporting in 1973, noted that rats continuously exposed to negative air ions over a prolonged period of time showed an induced reduction in their emotional behavior (response to handling following isolation) and also a concomitant reduction in brain serotonin levels measured post-sacrifice.[55] Although the behavioral data was noted to be limited in scope, it was consistent with earlier work by Frey in 1967. In 1974, Sulman published work on the treatment of Sharav wind sufferers, and noted that feelings of irritability, lack of concentration, headache, etc. were relieved in 75% of the patients by applying negatively ionized air.[143] In 1974, Assael noted significant changes in EEG with negative ion exposure (in both alpha wave amplitude and spread from the occipital to the

temporal/parietal and even frontal lobe areas). He also reported subjective feelings of relaxation and increased alertness in these treated patients. The alpha wave changes reverted to baseline within two hours of cessation of ionization.[6] In 1976, Olivereau noted improvement in psychomotor reactions of mice under stress when treated with negative air ions. Mice exposed to positive ions showed increased biting behaviors and a decreased pain threshold.[123] In 1978, Hawkins noted that air ion levels affected the circadian rhythm of cognitive performance. While controls showed rising levels of performance between 0900-1600 and a steady decline towards 2100, subjects exposed to negative ions maintained high levels of performance throughout. Those subjects exposed to positive ions showed an exaggerated decline in performance.[61] Also in 1978, Albrechtsen looked at subjective feelings of well-being along with mental performance in a sample of six females and found no significant effects. In the second phase of his experiment, they selected twelve subjects who consistently reported a feeling of discomfort when in a positive ion environment (i.e. subjectively sensitive) and tested them in an identical manner. He still found no significant differences in performance or feeling of wellness.[1]

In an experiment reported in 1980, Diamond demonstrated an increase in rat brain cortical weight (both somatosensory and occipital areas), along with decreased serotonin and cAMP in these same regions.[37] In 1981, Olivereau published work with rats that showed improved learning with negative ions and impaired short and long-term memory with positive ion exposure.[122] Also in 1981, Tom reported (in humans) increased feelings of energy and ability to concentrate after exposure to negative ions.[151] Lastly, in 1981, Charry and Hawkinshire, in one of the best controlled and most widely cited study in the literature, noted

definite mood changes (tension and irritability) in subjects after positive ion exposure. Probably even more significant is that they were able to discern a susceptible sub-population of subjects by using the autonomic lability score (ALS). This a physiological tool designed to measure homeostatic adaptation to physical stress. They also noted that the positive air ions showed significant effects in three different response systems (affective, perceptive-cognitive, and physiologic). Lastly, they determined that the negative mood state depended greatly on individual differences in susceptibility (as judged by the ALS testing).[27]

In 1982, Hedge and Eleftherakis found no significant effects of negative ions on simple reaction time or the EEG in 16 patients. A second study was done on thirty healthy, weather-sensitive subjects and no difference was found once again.[64] Also in 1982, Farmer and Bendix performed reasoning, psychomotor, and memory search tasks under varying ion conditions (four sessions over one week). They could not demonstrate any significant influence on scores. They also noted no changes in subjects' feeling of well-being.[43] Lastly, in 1982, Buckalew and Rizzuto found no effect of negative ionization on anxiety, but reported increased subjective feelings of relaxation and decreased tiredness. The feelings of relaxation corresponded to reduced irritability, decreased depression and tension, and an increased sense of calmness (i.e. overall improved mood and psychological state).[24]

The following year, Buckalew and Rizzuto, studied negative ionization's effect on cognitive performance tasks and, once again, showed no changes.[23] Also in 1984, Morton and Kerschner performed their first of three studies (see 1987 and 1990 also) looking at learning in children. In this study of normal achieving, learning-disabled, and mildly mentally

retarded children, they found that negative ions improved incidental memory and improved a dichotic listening task in the learning disabled group.[113]

In 1985, Dowdall, working with rats exposed to negative ions, showed increased responsiveness of neurons in the rat forebrain to serotonin, whereas positive ions showed a reduced responsiveness to 5HT. Exposure to negative ions also disrupted the normal circadian rhythm of responsiveness to 5HT (didn't decline in evening as it normally does). Positive ion exposure led to an inversion of the usual circadian rhythm of responsiveness.[40] Also in 1985, Baron and Russell reported findings which supported the concept that negative ions do influence behavior (moods and level of aggression). However, they noted that the effects were strongly mediated by personality types and the presence of provocation/anger. Therefore, the pattern of effects induced by negative ions were not uniformly beneficial.[15] Lastly in 1985, Delanue reported on negative ion therapy of 112 psychiatric patients (65% neuroses, 20% psychoses, 15% personality disorders). With short applications daily for 10-30 days he noted significant improvement or resolution of most of the target symptoms. In particular, he reported 80% normalization of insomnia symptoms, with the others showing some degree of amelioration of the insomnia. Virtually all of the anxiety symptoms were relieved, most of them entirely. The general feeling of "unwellness" experienced by nearly 90% of patients, resolved in over 65% of them.[36]

Bailey and Charry, writing in 1986, noted the lack of observed behavioral perturbations in rats, under any air ion condition (and for lengths of exposure of two to sixty-six hours).[8] In 1987, Brown and Kirk looked at the effects of positive and negative ionization on a visual vigilance task in forty male college students (under induced stress). There was a

significant increase in the percentage of visual signals detected in the group exposed to negative ionized air.[22] Also in 1987, Baron looked at 142 undergraduates in the first phase of a study, evaluating three cognitive tasks under differing ion conditions (proofreading, verbal problem-solving, and single-digit memory span). He found that negative ionization did affect cognitive ability in the male group (for two of three categories). Interestingly, he found that moderate levels increased scores, but that high levels had scores at or slightly below baseline (other authors have also referred to a decline in benefit at high levels but there is a lack, once again, of consistency). In the second part of his study, Baron looked at seventy-two more students for the same tasks plus two additional ones (letter copying and decision making). The results confirmed the first study's findings.[14] He again noted that, in general, the effects were more pronounced in men (this has also reported by previous authors, including Charry and Hawkinshire in 1981[27]). Lambert and Olivereau completed further studies in rats and reported beneficial effects of negative ionization on sleep, and a deterioration in normal sleep patterns with positive ions.[97] Hedge and Collis looked at twenty-eight females for both mood and cognitive task performance (simple mental and complex mental) under different conditions. They found no difference in the stress or arousal scores nor in the cognitive task scores.[65]

Continuing in 1987, Misiaszek reported the observed effects of short sessions of negative ions on eight bipolar patients (primarily because of their hyperactivity and agitation). He found a significantly beneficial effect on sleep difficulties, hyperactivity and distractability. There was no change, however, on delusional ideation or impaired thought processes.[111] Morton and Kerschner, on a follow-on study from 1984, tested nineteen retarded individuals

with a dichotic digits task. There were very definite effects of negative ions on the results although they were not thought to be either detrimental or beneficial (this testing is complex and the results should be reviewed directly by the interested reader). The negative ions appeared to influence arousal, and produced an alteration in information processing.[114] Lastly in 1987, Yates studied twenty-one Attention Deficit Disorder with Hyperactivity (ADDH) children and seven autistic children while they played in a negatively ionized room. Evaluation was done via blinded raters watching videotapes of these children, looking at activity, impulsivity, attention, reality orientation, and task performance). No significant change or effect was noted in the raters' overall appraisal under different ion conditions.[172]

In 1990, Morton and Kershner published the third of their studies. They studied forty normal-achieving and thirty learning-disabled children with a dichotic listening task. Negative ionization significantly affected the dichotic processing. Learning disabled subjects showed an enhanced left hemispheric processing, while normal-achieving subjects showed right hemispheric inhibition. They attributed this to an increased, ion-induced arousal.[112] The most recent study found was published in 1995 by Terman and Terman. They treated twenty-five subjects with DSM III-diagnosed Seasonal Affective Disorder with daily 30 minute sessions with negative ions at two different densities (low, high). A successful outcome was defined by greater than 50% reduction in symptom frequency/severity, as measured by patient diaries, standard depression rating scales, and corroboration by clinical impression. The low anion group had a 15% success rate, but the high anion group had a 58% success rate. This success rate is as good as with standard anti-depressant pharmaco-

therapy. All subjects who responded showed subsequent relapse after withdrawal of the ionization sessions.[147]

Of the entire group of published studies able to be found for the time period of 1957-1997, forty were ones which reported on neuropsychological (including neurophysiological and even neuroanatomical) and/or behavior effects in either laboratory animals or humans. Of these, twenty-nine had definite evidence of neuro-psycho-biological and/or behavioral effects from air ions of one or both polarities. Eleven of these studies showed no effects. The objective effects that were reported included EEG changes, alterations in central and peripheral serotonin levels, changes in size and weights of brain areas, changes in learning patterns, alterations in circadian patterns, etc. Subjective effects included mood elevation, changes in sense of alertness or arousal, changes in levels of anxiety, etc.

It would be ideal if these raw numbers could simply be added up and the score used to determine if there is an effect. This, of course, is too simplistic and does not take into account some other very important potential factors. Consider that:

1. The author may not have found all pertinent studies done in this time frame. This is especially true for studies done outside the US.

2. It is possible that additional negative results were obtained by researchers but just not published (a not uncommon phenomenon in the academic world).

3. Mixing animal and human data is risky, as any physiological and behavioral effects noted in the two species may not be comparable.

4. The magnitudes of change were often small, even if statistically significant, so biological *relevance* was not always established.

Note also that, in this review, the author did not critically analyze and report on the actual scientific validity of each of the studies nor on the actual magnitude of "significant" effects. For instance, several studies, such as the one from Silverman and Kornbleuh, did not describe ion measuring procedures. The studies from Chiles suggest a number of potentially confounding factors were not controlled for. Assael's EEG findings were very slight and not subjected to statistical analysis. Nefedov's work is in a report form with little in the way of methods , procedures, and data to evaluate. Tom did not control properly for temperature (high ambient temperature could well be a confounding factor) and did not specify exposure times. Hedge and Eleftherakis used non-validated weather-sensitivity questionnaires for separating this subgroup for comparison purposes. On the other hand, studies such as the ones by Charry and Hawkinshire, Baron and Russell, Baron, Albrechtsen, Bailey, Bailey and Charry, Morton & Kersher and Dowdall, appeared well designed and did control for most known confounding variables. The clinical trial by Terman and Terman, although lacking some valuable data on air ion levels, etc., was also well designed for the goal it set out to achieve. Therefore, these results would have to be considered more scientifically valid and should receive more weight. The others should not be discarded, but their results must be looked at with caution.

In summary, it seems apparent that a number of studies, several with very acceptable designs and controls, have demonstrated to a reasonable level that air ions ***are*** able to exert neuropsychobehavioral effect on higher animals. Most of the effects appear small or moderate in magnitude. It would also appear that these biologic effects could be described as ***significant*** in a number of instances. Additionally, the effects reported are ***not uniform***, and

results suggest that there might be subsets of the population who respond more than others. Certain ***pre-existing*** mental, emotional, or even physical states may also directly influence the quality and quantity of these effects. Lastly, all the effects noted seem to be ***transient***, occurring only in relation to the artificial exposure and disappearing at some interval of time after cessation of the exposure.

5. Temporal Relationship. In all laboratory experiments where an effect was shown, the effect followed exposure to the air ions. The effects were also transient, disappearing at varying time intervals after cessation of exposure to the ions. Studies on the Foehn, Sharav, and other winds also concluded that the certain ion changes preceded the arrival of the wind, and their rise coincided with the onset of patient symptoms. Although not everyone gives credence to the latter phenomenon, it would seem safe to conclude from laboratory investigations that exposure to air ions precedes onset of reported symptoms, and therefore "establishes" a temporal relationship.

6. Dose-Response Relationship. A large proportion of the studies either did not report at all on air ion measurements, reported only standard ion generator outputs given by manufacturers of the devices, or gave measurements but without them being obtained in the respiratory zone (i.e. reviewer does not know how many of the ions were "available" to the test subject). Lack of such information makes judgment on dose-response impossible. Also problematic are the tools for measuring psychological or behavioral responses. Many are of a relatively subjective nature and may be affected or modulated by a variety of extraneous

factors that may not be able to be controlled for. Consequently, grading responses might be difficult if not impossible (instead, just defining "response" or "no response" *a priori*). Again, this would confound one's ability to judge dose-response relationships. Several early studies, where accurate air ion measurements were obtained and reported, suggested that there may be a threshold for positive ions to show their adverse effect (estimated at about 2,000 positive ions/$cm^3$).[13, 129] Two other studies which also performed careful air ion measurements suggested that there is increasing benefit from negative ions up to a point, after which the beneficial effect falls off.[14] This is not universally agreed upon even in those who feel there is an effect to air ions. In summary, at this time there is insufficient extant data on air ion exposure and reported effect to attempt judgment on a dose-response relationship.

7. Strength of Association. As has been commented on before, the magnitude of effects seen on neuropsychological response and behavior has often been small despite being "statistically significant". In fact, many critics feel that the effect is too small to be of any real relevance because the changes noted would be overshadowed by other simultaneously occurring effects in the test subject's environment. Thus, they argue that even though there may be effects, they are insignificant. It is this argument which defines and separates the concepts of *biological activity* from *significant biological activity* from *health effects.* Because of the relative subtlety of most of the reported effects, one would have to conclude that this particular criteria is not strong.

## SECTION IV

## SUMMARY OF EXISTING DATA ON NEUROPSYCHOLOGICAL AND BEHAVIORAL EFFECTS OF AIR IONS

As a result of using this epidemiological tool for judging a possible cause-effect relationship between air ions and neuropsychological and behavioral effects, the following summary statements are offered:

1. Biologic Plausibility- Although not delineated or proven, there are existing hypotheses based on known biological, biochemical, and biophysical mechanisms that could explain a possible mechanism of action. The most credible hypotheses at present depend on the presence of an extremely sensitive receptor probably in the respiratory tract (such as neuroendocrine cells). Involvement of the neurohormone serotonin, both peripherally and centrally, is enticing and has considerable historical backing, but more recent work has cast significant doubts about its possible role . Despite this, the possibility (plausibility) exists that air ions can exert an effect on humans.

2. Specificity- Overall, there is a lack of specificity of effects attributed to air ions. Reasoning for this may be the amplification effect using an intermediate such as serotonin (linked to a broad range of physiologic and behavioral effects), but this is unproven. The two largest categories of effects are neuropsychological/behavioral and respiratory, so there has been some "narrowing" (focusing) of specificity over time. Also, in those studies showing an effect, there does seem to be some "specificity" in that negative air ions are essentially always associated with beneficial effects whereas positive ions are associated with adverse

effects. Essentially, the broad non-specificity of effects initially reported seems to be both consolidating and is focused on polarity-dependent differences. Specificity remains gray.

3. Coherence- From an evolutionary standpoint, the concept of an biological organism evolving in and being “in tune” with natural earth rhythms and naturally-occurring forces (e.g. electromagnetic fields and ambient space charge) is not unreasonable or irrational. By developing in conjunction with these geophysical factors, humans are likely to be equipped for both sensing significant alterations in them and for somehow responding or adapting to these changes. This ability may have become vestigial in our “more advanced” and complex evolutionary state. Factors which make this concept difficult to accept include the lack of ability to consciously perceive such forces, the extremely low levels at which they usually exist, our limitations in knowledge of the body’s internal bioelectrical processes and its response to external factors, and the apparent variations in individual susceptibility to such external factors. Based on studies reviewed and information presented here, the possibility of effect(s) on humans caused by air ions is coherent.

4. Consistency with Other Investigations- In general, one would have to conclude that the results of over sixty years of air ion investigations have been inconsistent and, not infrequently, in direct conflict. This is the biggest weakness of the whole debate. In many of the earlier investigations, these inconsistencies were often attributed to technique (poor design, lack of control of variables, lack of proper measurements, unsophisticated technology, etc.). Emerging more recently, however, is a series of studies involving neuropsychological and behavioral effects that have been very well designed and carried out in such a way that the results are not easily refutable. It may be that the inconsistency factor will

improve considerably over the next decade or two and a more consistent pattern will be forthcoming.

5. Temporal Relationship- The nature of an intervention trial is one of exposure and monitoring for effect, so a temporal relationship is inherent in non-control groups. If the biometeorological data is correct about winds such as the Foehn and Sharav, supposedly characterized by abnormally elevated levels and a ratio of positive air ions, then the onset of symptoms occurring with these changes would speak for a definite temporal relationship. In general, this criteria is not easily amenable to evaluation from an epidemiologic standpoint.

6. Dose Response- Due to both inconsistencies in ion measurement techniques and the subtle, subjective nature of many outcomes variables, there is insufficient data to judge a possible dose-response relationship between air ion concentrations (or negative:positive ion ratios) and human effect.

7. Strength of Association- Most of the outcomes, effects, and/or responses have been fairly subtle in their magnitude. Although statistically significant upon analysis in many cases, it is unknown to what degree the observed effects are clinically significant or relevant. This association must be judged to be fairly weak.

To summarize, there is sufficient scientific information to conclude that there are mild, transient, neuropsychological and/or behavioral effect of air ions on humans but which, unfortunately, do not follow a consistent or uniform pattern following exposure.

## SECTION V

## MODERN AIR CLEANING DEVICES

As the picture of the air ionization field of study becomes more complete, one should next become familiar with the present state of technology with respect to air cleaning devices and where air ionizers fit into this product line. This also brings the reader back a full circle as you recall this paper started out by introducing the concern for indoor air quality and the growing popularity of air cleaning devices.

An article in 1980 reported air cleaner sales in the neighborhood of $10 million per year.[144] In 1982 it was estimated that American's spent $150 million on air cleaners, the majority of that money being spent on small table-top units. Present economic figures have not been encountered, but the growth of the industry has been reportedly strong over the past fifteen years. Figures on individual vs. commercial uses of such devices, especially as sales cross over into many areas including agriculture, are also unavailable. At present there are no existing requirements for any of these devices to undergo testing to prove that they have a significant effect on levels of air ions.[155] As mentioned previously, there are still FDA restrictions on advertising for air ionizers (i.e. manufacturers cannot advertise any medical benefits).

Before specifically addressing air ionizers, a general discussion and some definitions of air cleaning terms would be valuable. There are three main strategies for reducing indoor air pollution. They are (1) source control (2) ventilation, and (3) air cleaning. The first two are considered by far and away the most important procedures.[3, 4, 154, 155] Air cleaning, by

itself, may be effective in reducing the levels of certain types of airborne contaminants, but cannot remove all pollutants typical of an indoor air environment. Of the types of pollutants (particles, gaseous contaminants, and radon with its daughter progeny) it is the particulate fraction that would be the primary target of air cleaners. There are three general types of domestic air cleaning devices[86, 155]:

1. mechanical filters - these range from single panel filters to standardized HEPA (high efficiency particulate-arresting) filters. Depending on their density and total surface area, these filters will trap various sizes of particulate matter with varying efficiency. They require regular changing.

2. electronic air cleaners - these are the electrostatic precipitators mentioned previously. With these devices, air is pulled into one end of the device, particles are imparted with a positive charge (typically from a corona discharge) as they pass through. A corona discharge process involves application of a high current to a wire tip which creates a strong field surrounding the needle. Electrons are stripped from or added to neutral particles passing through this field, creating charged particles. These charged particles (ions) are then electrostatically attracted to opposite-charged plates upon exiting the machine (thus, "precipitating" them out). Efficiencies of nearly 100% for pollen and 80-90% for tobacco smoke have been reported for better quality devices.[119, 156] Note that a positive corona is used despite being less effective than a negative one, because less ozone is reportedly generated by the former method.[86] Potential problems include the need for regular cleaning and maintenance (the latter also to minimize the production of ozone by the corona discharge tip). Electrostatic air

cleaners have been used effectively for years and are found in such diverse places as homes, industry clean rooms, and in closed space environments such as found in submarines.[42, 133]

3. ion generators - these generally are designed to produce ions of negative polarity (again, usually by means of a corona discharge) which are then dispersed by a small fan out into a room. The half life of these ions is fairly short, and the distance they travel depends on the degree of air movement and mixing and how quickly they encounter other molecules, particles, etc. The ions may attach themselves to particulates in the air, and these charged particles are then attracted to opposite-charged walls, floors, furnishings, etc. Although effective in reducing airborne particulate matter, this precipitation process may therefore soil walls, furnishings, etc. Some newer devices have now included a collector to attract the charged particles back to the unit, avoiding this deposition problem.

Note that some manufacturers are combining above-mentioned methods to produce "hybrid" devices. The most common combination would be one or more types of mechanical pre-filter combined with either an electrostatic precipitator or an ion generator. In addition to the above method of removing particulates, air cleaners may also contain adsorbants and/or reactive materials that may facilitate removal of gaseous material from indoor air. Radon and its decay products may be removed to some degree by various filter devices. This would depend on the degree of attachment to dust, which decay product is being removed, and the ventilation and filtration rates of the system.[86]

Lastly, although not technically classified as an air cleaner, mention should be given to air conditioning. By itself, it has been shown repeatedly to be effective in reducing indoor pollen and mold spores as well as decreasing the house dust mite burden. The mechanisms

here involve associated A-C filters (reduced pollen), a decreased intake of outside air due to recirculation (reduced pollen and mold spores), and a reduction in indoor humidity (less mold and dust mite growth). As mentioned previously, however, one of the most important contributors to the reduction in normal air ion levels indoors is air conditioning. This occurs because of the attraction of ions, particularly negatively charged ones, to the air conditioning ducts themselves. The longer the ductwork and the more angles the ducts take, the more loss of air ions. It has been suggested that air ionizers be added to HVAC (heating, ventilation, air conditioning) units, but the cost would be substantial. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) has looked at air ionization in the past but reportedly felt that if there was an effect, it was too small to necessitate or justify engineering changes.[98, 106]

Looking further at the question of possible health benefits from mechanical air cleaning devices, it should be recognized that there is relatively little published in the medical literature. An ad hoc committee was convened in 1987 at the request of the FDA to determine if standards could/should be recommended for portable air cleaners. Despite the (admittedly) small amount of clinical information available to them at that time, they concluded that there was inadequate data to establish or support the use of these devices at least in the prevention and treatment of allergic respiratory disease. The double blind studies that had been done demonstrated that "the addition of a central air cleaner to an air conditioning system could produce a small, often clinically *insignificant* further reduction in pollen load, and that symptom reduction compared with the major effect of the air conditioning itself".[119, 155] No recent updates on these recommendation were found.

The last note on air cleaners, and ionizers in particular, is that the ionization process itself can produce ozone, a recognized respiratory irritant. This was one of the primary criticisms of earlier devices which led to the FDA restrictions in the early 1960's. However, technological advances now make it possible for air ionizers to produce negligible amounts of ozone as a by-product. Interestingly, however, the marketing "pitch" has recently changed, and now several commercial manufacturers of air purifying devices are actually *promoting* the presence of ozone (in very low, "safe" levels). The claim is that ozone neutralizes contaminants in the air via oxidation of organic compounds to $CO_2$ and $H_2O$. Some commercial products are marketed primarily as ionizers, but with ozone production as an added benefit Others advertise ozone production as the *primary* air cleaning process. It should be noted that very high levels of ozone may well have merit in this process, but would be decidedly unsafe for human exposure. The question, then, is whether very low levels of ozone have any significant amount of effectiveness. Certainly there is a growing body of anecdotal reports and promotional literature on this that affirms this notion, but there is little in the way of scientific backing. Many recognized experts in the field state that there is no such thing as a "safe" level of ozone, and that any amount has some adverse effects on the respiratory tract. In any case, a full discussion of ozone generating devices is beyond the scope and purpose of this paper. The reader is referred to the excellent general review article by Boeniger for additional details.[19] Here, once again, the major strategies recommended are additional ventilation with clean air and controlling the source of pollutants and contaminants.

To summarize, this section has been devoted to surveying presently available air cleaners/purifiers including ion generating devices (especially since this is the only function

for which these latter devices can be legally marketed). The associated issue, and the one most of this paper has been devoted to, is whether the charged ions themselves may have an independent, *direct* biological effect in addition to their ability to electrostatically precipitate airborne particles.

# SECTION VI

# CONCLUSIONS, RECOMMENDATIONS, and FINAL REMARKS

## Conclusions and Recommendations

1. Despite a large body of scientific literature, a clear majority demonstrating a biologic effect of air ions, many scientists still reject the concept or possibility outright. Inconsistencies and conflicting results in many reports indicate lack of incontrovertible proof of effect, and lack of any proof leads to lack of belief/consensus. However, based on several recent, well done laboratory and clinical studies, it would be reasonable to conclude that there exist biological, maybe even biologically *significant,* effects of air ions on certain neuropsychological and/or behavioral processes. As noted, however, the magnitude is often small and the biological relevance (including health effect) remains unanswered at this time.

2. There also appears to be enough evidence to suggest that there is a sub-population of individuals who may be more sensitive to changes in air ion levels, and thus they may be more susceptible to feelings of discomfort or possibly ill health. There is also a suggestion that most beneficial effects of negative ions are noted when the organism is already under some degree of stress or has existing pathology (injury, illness, or even advancing age). The pre-existing personality type (or possibly other intrinsic traits?) may also turn out to have a bearing on the quality of the response. This lack of a uniform or characteristic response would make it difficult and probably unwise to recommend indiscriminate, non-selective use of artificial ionizers for the general population or for routine indoor air “conditioning”.

3. There is not enough evidence to imply that there is an existing or impending public health crisis due to ion depletion/alteration in indoor environments. This does not mean that ion depletion or alteration does not play a role in indoor air quality issues. However, it should be considered in conjunction with a multitude of other known factors (e.g. $CO_2$, VOC's, etc.) which may potentially affect both indoor comfort and health.

4. Of the biologic effects reported, the only consistent trend noted was that negative ions tend to be reported to show beneficial effects while positive ions tend to be associated with adverse effects. These effects are often small and may be overshadowed by other co-existing effects.

5. The biologic effects of air ions are independent of the electrostatic precipitant effect on airborne particles, although the latter process may have some value itself for "cleaning" air contaminated with particulate matter (this would be considered a secondary strategy).

6. Pollution, whether outdoors or indoors, has a marked influence on air ion levels as well as its potential direct effect(s) on organisms such as humans. The relevance of the associated air ion depletion to health, from a macroenvironmental perspective, has not yet been determined.

7. The "consensus vacuum" regarding air ions has allowed commercial exploitation of this area as concern over health and air quality grows. The presence of conflicting data and the absence of definitive proof and consensus allows negative ion promoters a choice of which data are to be presented as fact. This has created confusion, polarization of opinion, and occasionally outright deceptive practices, and it serves to degrade the credibility of the

entire field of study. The one-sided marketing push also does a disservice to the public by not presenting balanced information with which people can make a truly informed opinion or decision.

8. Improved technology has made the production of ozone, as a by-product of ionization, essentially an obsolete problem. However, low level ozone itself is now being promoted by some for enhanced air cleansing. Caution should be exercised when dealing with manufacturers who are promoting ozone since, unlike negative air ions, it has *known* adverse health effects.

9. In order to prospectively avoid criticism, future studies involving air ions should follow certain criteria so as to control for known confounding variables. Recommended criteria have been enumerated by several authors [26, 49, 79] and by the American Institute for Biomedical Climatology (which , amongst other activities, functions as a "clearinghouse" for studies dealing with air ionization).

10. There are few, if any, large scale epidemiological studies that demonstrate significant benefits of negative air ionization. If the ion generator manufacturers truly believe in their product and are committed to gaining a consensus within the scientific community, then they should be willing to step forward and support some well-designed, large scale studies. The ideal setting would be large buildings or offices which have installed such devices. Large scale prospective case-control studies could be accomplished in these realistic settings looking at objective measures such as missed work days and changes in productivity, as well as more subjective measures such as fatigue, mood, etc. Similarly, more clinical studies such as the one looking at Seasonal Affective Disorder could, and should, be designed

and carried out by medical practitioners with interest and experience in this area. Without such studies, this field will continue to limp along without a firm consensus on the actual value of air ions.

11. Although a recommendation for wholesale, indiscriminate use of air ionizers cannot be made at this time, a reasonable approach would be to advise individuals (or companies) interested in purchasing an air ionizer that they should ***contract*** with the manufacturers for a free trial period (minimum of a week, preferably up to a month). If tangible or perceived benefit is obtained by the prospective buyer and the sale price is affordable, then there should be little trepidation or ethical concern on the health care professional's part in supporting subsequent purchase. On the other hand, if no benefit is noted during such a trial, the device should be returned without hesitation or penalty. Without such a trial period or a similar money-back guarantee, a conscientious health care provider should remain hesitant in recommending or concurring with the *de novo* purchase of such a device.

## Final Remarks

During the writing of the final draft for this paper and after conclusions had been finalized based on the evidence presented, a copy of the translated report "Aero-Ionization In Medicine", written in 1961 by A.A. Minkh of the (former) U.S.S.R., was obtained. A comparison of the thoughts, findings and conclusions from 36 years ago is both interesting and instructive. From this report, the following passages are excerpted:

> The current idea of the influence of the environment on the human body indicates the need for taking into consideration all possible influences of

> this medium, beginning with the marked ones and ending with the hardly perceptible ones (but capable of exerting an essential effect on the organism after prolonged action). Atmospheric ionization under ordinary conditions of life should be regarded as one of the latter factors of low intensity. Its variations...undoubtedly are of practical significance for certain groups of patients, for persons sensitive to the change in climate and weather, weakened by some disease or by other prolonged work strain.
>
> It is perfectly obvious that the influence of aero-ionization should be studied against the background of certain interrelationships with other meteorological factors, since it is expressed in a *combination* of effects of climatic conditions and weather conditions.
>
> The fact of the physiologic effect of aero-ions is indisputable. It has been established in numerous experiments on animals and clinically. Artificially ionized air exerts a definite influence on many systems and functions of the body, which may be positive or negative depending on the concentrations of ions, polarity, mobility, and the duration of effect. Of considerable significance thereby, are the individual characteristics of the body, particularly the condition of the autonomic nervous system, individual sensitivity to aero-ions, and factors of a psychogenic nature. [110]

From Minkh's writing, it would appear that conclusions on the effects of air ions have really not changed all that much in the past thirty-six years.

## BIBLIOGRAPHY


1. Albrechtsen, O., "The Influence of Small Atmospheric Ions on Human Well-being and Mental Performance", *International Journal of Biometeorology,* Vol. 22, No. 4, 1978, pp. 249-262

2. Ancker, K, "Electrostatic Charge in Office Environments", *Indoor Air; Proceedings of the 3rd International Conference on Indoor Air Quality and Climate,* Vol. 3, Aug 20-24, 1984, pp. 157-162

3. Anon., "Air Purifiers", *Consumer Reports,* Feb 1989, pp. 88-93

4. Anon., "Household Air Cleaners", *Consumer Reports,* Oct 1992, pp. 657-662

5. Anon., "The Science of Sacred Places", *Backpacker,* Feb 1991, pg. 36

6. Assael, M. and Pfeifer, Y., "Influence of Artificial Air Ionisation on the Human Electro-encephalogram", *International Journal of Biometeorology,* Vol. 18, No. 4, 1974, pp. 306-312

7. Bach, C., "The Properties of Air-ions: A Concise Summary," *Ions for Breathing,* Chapters 1 and 2, Pergamon Press, Oxford, 1967

8. Bailey, W. and Charry, J., "Behavioral Monitoring of Rats During Exposure to Air Ions and DC Electric Fields", *Bioelectromagnetics,* July 1986, pp. 329-339

9. Bailey, W., "Acute Exposure of Rats to Air Ions: Effects on the Regional Concentration and Utilization of Serotonin in Brain", *Bioelectromagnetics,* 8 (2), 1987, pp. 173-181

10. Bailey, W., "Biological Effects of Air Ions: Fact and Fancy Concerning Serotonin, *AIMC Conference on Environmental Ions and Related Biological Effects,* Oct 30, 1982, pp. 91-120

11. Bailey, W., *Air Ions: Physical and Biological Aspects,* Chapter 7, CRC Press, Inc., Boca Raton, Florida, 1984

12. Bailey, W., *Personal Telephone and Internet Communication*

13. Baker, C., *Visual Capabilities in the Space Environment*, Pergamon Press, New York, 1980, pp. 117-118

14. Baron, R., "Effects of Negative Ions on Cognitive Performance", *Journal of Applied Psychology,* Vol. 72, No 1, 1987, pp. 131-137

15. Baron, R. and Russell, G., "Negative Ions and Behavior: Impact on Mood, Memory, and Aggression Among Type A and Type B Persons", *Journal of Personality and Social Psychology,* Vol. 48 No. 3, 1985, pp. 746-754

16. Barron, C., "Effects of Electric Fields and Negative ion Concentrations on Test Pilots", *Aerospace Medicine,* January 1964, pp. 20-23

17. Beckett, J. "Air Ion Measurement", *Proceedings of International Conference of Ionization of the Air,* Oct 16-17, 1961, Vol. 1, pg. III-1 to III-15

18. Ben-Dov, I., "Effect of Negative Ionisation of Inspired Air on the Response of Asthmatic Children to Exercise and Inhaled Histamine", *Thorax,* Vol. 38, 1983, pp. 584-588

19. Boeniger, M., "Use of Ozone Generating Devices To Improve Indoor Air Quality", *American Industrial Hygiene Association Journal,* Vol. 56, June 1995, pp. 590-598

*20.* Brandt, A. D., "The Influence of Atmospheric Ionization Upon The Human Organism", *The Journal of Industrial Hygiene, Vol. 15, No. 5, Sept 1933*

21. Brooks, B., "Indoor Air Pollution: An Edifice Complex", Clinical Toxicology, Vol. 29, No. 3, 1991, pp. 315-374

22. Brown, G. and Kirk, R., "Geophysical Variables and Behavior: XXXVIII. Effects of Ionized Air On The performance of a Vigilance Task", *Perceptual and Motor Skills,* 1987, Vol. 64, pp. 951-962

23. Buckalew, L. and Rizzuto, A., "Negative Air Ion Effects on Human Performance and Physiological Condition", *Aviation, Space and Environmental Medicine,* Aug 1984, pp. 731-734

24. Buckalew, L and Rizzuto, A., "Subjective Response to Negative Air Ion Exposure", *Aviation, Space and Environmental Medicine, Vol. 53,* Aug 1982, pp. 822-823

25. Carlton, R., "Discussion of Dr. Robert Kavet's Paper on Application of Ion Research to Environmental Issues", *AIMC Conference on Environmental Ions and Related Biological Effects,* Oct 30, 1982, pp. 29-61

26. Charry, J. and Kavet, R., *Air Ions: Physical and Biological Aspects,* Chapter 6, CRC Press, Inc., Boca Raton, Florida, 1984

27. Charry, J. and Hawkinshire, F., "Effects of Atmospheric Electricity on Some Substrates of Disordered Social Behavior", *Journal of Personality and Social Psychology,* Vol. 41, No. 1, 1981, pp. 185-197

28. Charry, J., "Regional Turnover of Nonrepinephrine and Dopamine in Rat Brain Following Acute Exposure to Air Ions", *Bioelectromagnetics,* 6(4), 1985, pp. 415-425

29. Chiles, W., "Effects of Ionized Air on Decision making and Vigilance Performance", *Technical Documentary Report No. MRL-TDR 62-51,* Wright-Patterson Aerospace Medicine Division, May 1962

30. Chiles, W., "A Study of the Effects of Ionized Air on Behavior", *Wright Air Development Division (WADD) Technical Report 60-598,* Nov 1960

31. Corrado, A.G., "Measurement of Atmospheric Ion Density in Southern Washington", *Proceedings of International Conference of Ionization of the Air,* Oct 1961, Vol. 1, pp. X-1 to X-8

32. Daniells, W, "Trial of a Negative Ion Generator Device in Remediating Problems Related to Indoor Air Quality", *Journal of Occupational Medicine,* Vol. 33, No. 6, June 1991, pp. 681-687

33. Dantzler, B., "The Effect of Positive and Negative Air Ions on Bronchial Asthma", *Annals of Allergy,* Vol. 51, Sept 1983, pp. 362-366

34. David, T., "Polarized Air As An Adjunct in the Treatment of Burns", *American Journal of Physical Medicine,* 39:111, 1960

35. Davis, J., "Review of Scientific Information on the Effects of Ionized Air on Human Beings and Animals", *Aerospace Medicine,* Jan 1963, pp. 35-42

36. Deleanu, M., "Influence of Aeroionotherapy on Some Psychiatric Symptoms", *International Journal Biometeorology,* Vol. 29, no. 1, 1985, pp. 91-96

37. Diamond, M., "Environmental Influences of Serotonin and Cyclic Nucleotides in Rat Cerebral Cortex", Science, Vol. 210, 1980, pp.652-654

38. Diamond, M., "Uppers and Downers in the Air", *Psychology Today,* Jun 1980, pg. 128

39. Dolezalek, H., "Remarks on the Physics of Atmospheric Ions (Natural and Artificial)", *International Journal of Biometeorology,* Vol. 29, No. 3, 1985, pp. 211-221

40. Dowdall, M., "Effect of Atmospheric Ions on Hippocampal Pyramidal Neuron Responsiveness to Serotonin", *Brain Research,,* 342, 1985, pp. 103-109

41. Duffee, R. and Koontz, R, "Behavioral Effects of Ionized Air On Rats", *Psychophysiology,* Vol. 1, No. 4, Apr 1965, pp. 347-359

42. Edge, C., "Indoor Air Quality; Lessons From Submarine Environmental Systems", *Proceedings of the ASHRAE,* IAQ 87, "Practical Control of IAQ", 1987, pp. 255-258

43. Farmer, E. and Bendix, G., "Geophysical Variables and Behavior; V. Human Performance in Ionized Air", *Perceptual and Motor Skills,* 1982, Vol. 54, pp. 403-412

44. Finnegan, M., "Effect of Negative Ion Generators in a Sick Building", *British Medical Journal,* Vol. 294, May 9, 1987, pp. 1195-1196

45. First, M., "Effects of Air Ions", *Science,* Vol. 210, Oct 1980, pp. 715-716

46. Fisher, A., "Environmental Influences on Uptake of Serotonin and Other Amines", *Environmental Health Perspectives,* Vol. 35, Apr 1980, pp. 191-198

47. Fornof, K., "Stress and Physiological, Behavioral and Performance Patterns of Children Under Varied Air Ion Levels", *International Journal of Biometeorology,* 32(4), Nov 1988, pp. 260-270

48. Frey, A., "Modification of the Conditioned Emotional Response by Treatment with Small Negative Air Ions", *Journal of Comparative and Physiological Psychology,* Vol. 63, No. 1, 1967, pp. 121-125

49. Frey, A., "Experimental Controls and Biological Experiments with Atmospheric Ions", *Aerospace Medicine,* February 1965, pg. 121-123

50. Frey, A., "Human Reactions to Air Ions", *Proceedings of International Conference of Ionization of the Air,* October 16-17, 1961, Vol. 2, pg. XXI-1 to XXI-18

51. Froger, C., "The Effects of Negative Ions Produced by Fibers of Polyvinyl Chloride", *Proceedings of International Conference of Ionization of the Air,* October 16-17, 1961, Vol. 2, pg. XIV-1 to XIV-7

52. Giannini, A., "Anxiety States: Relationship To Atmospheric Cations and Serotonin", *Journal of Clinical Psychiatry,* 44:7, July 1983, pp. 262-264

53. Giannini, A., "Reversibility of Serotonin Irritation Syndrome With Atmospheric Anions", *Journal of Clinical Psychiatry,* 47:3, March 1968, pp. 141-143

54. Giannini, A., "Serotonin Irritation Syndrome: An Hypothesis", *International Journal Psychiatry in Medicine,* Vol. 9 (2), 1978-79, pp. 199-204

55. Gilbert, G., "Effect of negative Air Ions Upon Emotionality and Brain Serotonin Levels in Isolated Rats", *International Journal of Biometeorology,* Vol. 17, 1973, pp. 267-275

56. Goldsmith, D., "Importance of Causation For Interpreting Occupational Epidemiological Research", *Occupational Medicine: State of the Art Reviews,* Vol. 11,No. 3, Jul-Sep 1996, pp. 433-437

57. Goldstein, N., "Negative Air Ions as a Source of Superoxide", *International Journal of Biometeorology,* Vol. 36, 1992, pp. 118-122

58. Hansell, C., Dr., "Post Conference Comment by the General Chairman", *Proceedings of International Conference of Ionization of the Air,* October 17, 1961, Vol. 2, pg. XXVI-1 to XXVI-12

59. Hansell, C., "An Attempt to Define 'Ionization of the Air'", *Proceedings of International Conference of Ionization of the Air,* October 16-17, 1961, Vol. 1, pg. I-1 to I-10

60. Hawkinson, T., "The Industrial Hygiene Significance of Small Air Ions", *American Industrial Hygiene Association Journal,* Vol. 42, October 1981, pp. 759-761

61. Hawkins, L and Barker, T., "Air Ions and Human Performance", *Ergonomics,* Vol. 21, 1978, pp. 273-278

62. Hawkins, L., "Air Ions and the Sick Building Syndrome", *Indoor Air-Proceedings of the 3rd International Conference on Indoor Air Quality and Climate,* Vol. 3, August 20-24, 1984, pp. 197-200

63. Hawkins, L., "The Influence of Air Ions, Temperature and Humidity on Subjective Well-being and Comfort", *Journal of Environmental Psychology,* Vol. 1, 1989, pp. 279-292

64. Hedge, A. and Eleftherakis, E.., "Air Ionization: An Evaluation of its Physiological and Psycho-logical Effects", *Annals of Occupational Hygiene,.* Vol. 25 No. 4, 1982, pp. 409-419

65. Hedge, A. and Collis, G., "Do Negative Air Ions Affect Human Mood and Performance?", *Annals of Occupational Hygiene.,* Vol. 31, No. 3, 1987, pp. 285-290

66. Hennekens, C., "Statistical Association", Chapter 3, *Epidemiology in Medicine,* 1st Edition; Little, Brown and Company, Boston, 1987

67. Hinsull, S., "The Effect of Negative Air Ionization on the Growth of Four Generations of Laboratory Rats", *Intnl. Journal of Biometeorology,* Vol. 28, No. 2, 1984, pp. 163-168

68. Hudson, C., "A Case of Weather Sensitivity", *Alaska Medicine,* Vol. 23, No. 3, May/June 1981, pp. 41-42

69. Inbar, O., "The Effects of Negative Air Ions on Various Physiological Functions During Work in a Hot Environment", *International Journal of Biometeorology,* Vol. 26, No. 2, 1982, pp. 153-163

70. Johnson, G., "The Electrical Environment and HVDC Transmission Lines", *AIMC Conference on Environmental Ions and Related Biological Effects,* Oct 30, 1982, pp. 65-82

71. Jones, D., "Effect of Long-term Ionized Air Treatment on Patients with Bronchial Asthma", *Thorax,* Vol. 31, 1976, pp. 428-432

72. Jordan, J. and Sokoloff, B., "Air Ionization, Age, and Maze Learning of Rats", *Journal of Gerontology,* Vol. 14, No. 344, 1959

73. Kavet, R., "Application of Ion Research to Environmental Issues", *AIMC Conference on Environmental Ions and Related Biological Effects,* October 30, 1982, pp. 1-28

74. Kavet, R., "Hypothetical Neural Substrates for Biological Responses to Air Ions", *Air Ions: Physical and Biological Aspects,* Chapter 8, CRC Press, Inc., Boca Raton, Florida, 1984, pp. 162-175

75. Kellogg, E., "Air Ions: Their Possible Biological Significance and Effects", *Journal of Bioeletricity,* Vol. 3 (1&2), 1984, pp. 119-136

76. Kellogg, E., "Superoxide Involvement in the Bactericidal Effects of Negative Air Ions on Staphylococcus Albus", *Nature,* Vol. 281, Oct 4, 1979, pp. 400-401

77. Kellogg, E., "Long-term Biological Effects on Air Ions and D.C. Electric Fields on Namru Mice: First Year Report", *International Journal of Biometeorology,* Vol. 29, No. 3, 1985, pp. 253-268

78. Kellogg, E., "Long-Term Biological Effects of Air Ions and D.C. Electric Fields on Namru Mice: Second Year Report", *International Journal of Biometeorology,* Vol. 29, No. 3, 1985, pp. 269-283

79. King, G., "Air Ionization and Its Effects on Well Being and Stress and its Biological Effects (The Third Wave)", *Paper Presented to: The International Academy of Preventive Medicine,* Mar 10, 1979, Fairmont Hotel, Dallas, Texas

80. Knoll, M., "Influence of Light Atmospheric Ions on Human Visual Reaction Time", *Proceedings of International Conference of Ionization of the Air,* Oct 16-17, 1961, Vol. 2, pg. XVIII-1 to XVIII-25

81. Kornblueh, I., "Air Ions and Human Health", *Seminar on Human Biometeorology,* Public Health Service Pub. No. 999-AP-25, USDHEW/PHS/Bureau Of Disease Prevention and Environmental Control/National Center for Air Pollution Control, 1967

82. Kornblueh, I., "Artificial Air Ionization in Physical Medicine", *American Journal of Physical Medicine,* 34:618, 1955

83. Kornblueh, I, "The Future of Artificial Ionization of the Air", *Proceedings of International Conference of Ionization of the Air,* Oct 16-17, 1961, Vol. 2, pg. XXIII-1 to XXIII-6

84. Kornblueh, Igho H., "Relief From Pollinosis in Negatively Ionized Rooms", *American Journal of Physical Medicine,* Vol. 37: No. 18, 1958

85. Kotaka, Sadao, "Effects of Air Ions on Microorganisms and Other Biological Materials", *CRC Critical Reviews in Microbiology,* Nov 1978, pp. 109-149

86. Krafthefer, B., "Electronic Air Cleaners and the Indoor Environment", *Proceedings of An Engineering Foundation Conference on Management of Atmosphere in Tightly Closed Spaces,* 1984, pp. 95-102

87. Kreiss, K., "The Epidemiology of Building-Related Complaints and Illness", *Occupational Medicine: State of the Art Reviews,* Vol. 14, No. 4, Oct-Dec 1989, pp. 575-576

88. Kroling, P. "Natural and Artificially Produced Air Ions- A Biologically Relevant Climate Factor?", *International Journal of Biometeorology,* 1985, Vol. 29, No. 3, pp. 233-242

89. Krueger, A., "Influence of Air Ions on Certain Physiological Functions", in *Medical Biometeorology,* Elsevier Publishing Co., Amsterdam, 1963

90. Krueger, A.., "Are Air Ions Biologically Significant? A Review of a Controversial Subject", *International Journal of Biometeorology,* Vol. 16, No. 4, 1972, pp. 313-322

91. Krueger, A., "The Biological Effects of Air Ions", *International Journal of Biometeorology,* Vol. 29, Number 3, 1985, pp. 205-206

92. Krueger, A., "Biological Effects of Ionization of the Air", in *Progress in Biometeorology (Vol. 1, Part 1B, Period 1963-1970),* Zeitlinger Pub, Amsterdam, 1974, pp. 335-344

93. Krueger, A. and Kotaka, S., "The Effects of Air Ions on Brain Levels of Serotonin in Mice", *International Journal of Biometeorology,* Vol. 13, No. 1, 1969, pp. 25-38

94. Krueger, A., "Biological Impact of Small Air Ions", *Science,* Vol. 193, Number 24, September 1976, pp. 1209-1213

95. Krueger, A., "Some Observations on the Biological Effects of Gaseous Ions", *Proceedings of International Conference of Ionization of the Air,* October 16-17, 1961, Vol. 2, pg. XVII-1 to XVII-6

96. Krueger, A., "The Biological Mechanisms of Air Ions in Action", *Journal of General Physiology,* Vol. 43, 1960, pp. 533-540

97. Lambert, J. and Olivereau, J., "Effects of Previous Aeroionization on Consecutive Waking and Sleeping Phases in Rats", *Intnl. Journal of Biometeorology,* Vol. 31, No. 4, Apr 1987, pp. 323-328

98. Laws, C., "Air Ions in the Working Environment", *The Heating and Ventilating Engineer,* May 1982, pg. 18-20

99. Lehtimaki, M., "Measurement of Air Ions", *Indoor Air-Proceedings of the 3rd International Conference on Indoor Air Quality and Climate,* Vol. 3, Aug 20-24, 1984, pp. 187-189

100.Levine, A.., "Clinical Study of Negative Ion Therapy", *Proceedings of Inter-national Conference of Ionization of the Air,* Oct 16, 1961, Vol. 2, pg. XVI-1 to XVI-8

101.Licht, S., "Medical Climatology", *Library of Congress Catalog Card No,. 64-10010,* Waverly Press, Inc., Baltimore Maryland, 1964

102.Lipin, I., "Effect of Positive Ionisation of Inspired Air on the Response of Asthmatic Children to Exercise", *Thorax,* 39(8), Aug 1984, pp. 594-596

103.Lipinski, B., "Biological Significance of Piezoelectricity in Relation to Acupuncture, Hatha Yoga, Osteopathic Medicine and Action of Air Ions", *Medical Hypotheses,* Vol. 3, No. 1, Jan-Feb 1977, pp. 9-12

104.Lord, D., "Air Quality in Western Culture: A Short History", *Proceedings of the ASHRAE Conference*, IAQ 86, Atlanta, Georgia, 1986

105.McDonald, R., "Some Psychomotor and Physiological Tests On Humans Exposed to Air Ions", *Aerospace Medicine,* Feb 1967, pp. 145-148

*106.*McNall, P., "Control of Indoor Air Quality by Means of HVAC Systems", *Proceedings of the ASHRAE Conference, IAW 1986, Atlanta, Georgia*

107.Maczynski, B., "Effect of the Presence of Man on the Air Ion Density in an Office Room", *International Journal of Biometeorology,* Vol. 15, No.1, Mar 1971, pp. 11-21

108.Makela, P., "Studies on the Effects of ionization on Bacterial Aerosols in a Burns and Plastic Surgery Unit", *Journal of Hygiene,* Vol. 83, No. 2, October 1979, pp. 199-206

109.Minehart, J., "Artificial Ionization and the Burned Patient", *Medical Science,* Mar 25, 1958, pp. 363-367

110.Minkh, A., "Aero-ionization In Medicine", Translated by the Office of Technical Services, US Dept. of Commerce, Washington, DC (OTS 61-31,621), 27 Sep 1961

111.Misiaszek, J., "The Calming Effects of Negative Air Ions on Manic Patients: A Pilot Study", *Biological Psychiatry,* Vol. 22, 1987, pp. 107-110

112.Morton , L., "Differential Negative Air Ion Effects on Learning Disabled and Normal-Achieving Children", *International Journal of Biometeorology,* Vol. 34, 1990, pp. 35-41

113.Morton, L., "Negative Air ionization Improves Memory and Attention in Learning-Disabled and Mentally Retarded Children", *Journal of Abnormal Child Psychology,* Vol. 12, No. 2, 1984, pp. 353-365

114.Morton, L., "Negative Ion Effects on Hemispheric Processing and Selective Attention in the Mentally Retarded Child", *Jnl. of Mental Deficiency Research,* Vol. 31, 1987, pp. 169-180

115.Motley, H., "Environmental Air Pollution, Emphysema and Ionized Air", *Diseases of the Chest,* Vol. 50, No. 4, Oct 1966, pp. 343-352

116.Meucher, H., "Meteorological Influence on Reaction Time, Flicker Fusion Frequency, Job Accidents, And Use of Medical Treatment", *Perceptual and Motor Skills,* Vol. 12, 1961, pp. 163-168

117.Nagy, R., "Nature of Air Ions Generated by Different Methods", *Proceedings of International Conference of Ionization of the Air,* Oct 19, 1961, Vol. 1, pp. II-1 to II-13

118.Nefedov, Y., "The Aero-Ionic Composition of Pressurized Cabin Air and its Influence on the Human Body", *Reports Presented at Soviet Conference on Space Biology and Medicine,* (NTIS JPRS-38596), Nov 1966, pp. 32-46

119.Nelson, H., "Recommendations for the Use of Residential Air-Cleaning Devices in the Treatment of Allergic Respiratory Diseases", *Journal of Allergy & Clinical Immunology,* Vol. 82, No. 4, Oct 1988, pp. 661-669

120.Nogrady, S., "Ionisers in the Management of Bronchial Asthma", *Thorax,* Vol. 38, 1983, pp. 919-922

121.Nylen, P., "Physical and Chemical Environment at VCT Work Stations: Air Ions, Electrostatic Fields and PBC's", *Indoor Air-Proceedings of the 3rd International Conference on Indoor Air Quality and Climate,* Vol. 3, Aug 20, 1984, pp. 163-167

122.Olivereau, J., "Effects of Air Ions on Some Aspects of Learning and Memory of Rats and Mice", *International Journal of Biometeorology,* Vol. 25, No. 1, 1981, pp. 53-62

123.Olivereau, J., "Atmospheric Ionization and its Effects on the Behavior of Animals and Man", *Annee Psychologique,* 1976, pp. 213-244

124.Osterballe, O., "Influence of Small Atmospheric Ions on the Airways in Patients with Bronchial Asthma", *Allergy,* Vol. 34, 1979, pp. 187-194

125.Palti, Y., "The Effect of Atmospheric Ions on the Respiratory System of Infants", *Pediatrics,* Vol. 38, No. 3, Sept 1966, pp. 405-411

126.Reiter, R., "On the Presence and Generation of AC and DC Electric Fields and Small Ions in Closed Rooms as a Function of Building Materials, Utilization, and Electrical Installation", *Journal of Geophysical Research,* Vol. 90, No. D-4, Jun 30, 1985, pp. 5936-5944

127.Rheinstein, J., "Statistical Evaluation of the Influence of Atmospheric Ions on the Simple Reaction Time and on the Optical Moment", *Proceedings of International Conference of Ionization of the Air,* Oct 16-17, 1961, Vol. 2, pg. XIX-1 to XIX-18

128.Robinson, N. and Dirnfeld, F., "The Ionization State of the Atmosphere as a Function of the Meteorological Elements and of Various Sources of Ions", *International Journal of Biometeorology,* Vol. VI, No. 2, 1963, pp. 101-110

129.Rosenberg, B., "A Study of Atmospheric Ionization: Measurements of the Ion Conditions in an ATC laboratory and a Review of the Literature of Ion Effects on Performance", *National Aviation Facilities Experimental Center,* Report No. NA-72-19, May 1972

130.Rosenthal, I., "A Working Hypothesis for Negative Ion Generators", *Experientia,* Vol. 39, 1983, pp. 718-719

131.Rosenthal, I., "Effects of Negative-Charged Atmosphere on Microorganisms", *Journal of Applied Bacteriology,* 46, 1979, pp. 451-454

132.Rosenthal, I., "Superoxide Involvement in Negative Air Ion Effects", *Nature,* Vol. 288, Dec 1980, pg. 739

133.Schaefer, K., "Interaction of Aerosols and Air Ions", *Proceedings of International Conference of Ionization of the Air,* Oct 1961, Vol. 1, pg. IV-1 to IV-15

134.Sikana, R., "Some Topics Concerning Experimental Investigation of Air Ions", *Proceedings of International Conference of Ionization of the Air,* Oct 1961, Vol. 1, pg. IX-1 to IX-25

135.Silverman, D. and Kornbleuh, I., "Effect of Artificial Ionization of the Air on the Electroencephalogram", *American Journal of Physical Medicine,* Vol. 36, pp. 352-358

136.Slote, L., "An Experimental Evaluation of Man's Reaction to an Ionized Air Environment", *Proceedings of International Conference of Ionization of the Air,* Oct 16-17, 1961, Vol. 2, pg. XX-1 to XX-22

137.Sovijarvi, A., "Effect of Air Ionization on Heart Rate and Perceived Exertion During a Bicycle Exercise Test A Double-blind Cross-over Study", *European Journal of Applied Physiology and Occupational Physiology.,* 41, 1979, pp. 285-291

138.Soyka F. "*The Ion Effect*", E.P. Dutton and Co., Inc., New York, 1977

139.Spengler, J., "Indoor Air Pollution and Public Health Concerns", *AIMC Conference on Environmental Ions and Related Biological Effects,* Oct 1982, pp. 126-149

140.Strindehag, O., "Ventilation Measures That Affect the Content of Air Ions In Office Premises", *Indoor Air, Proceedings of the 3rd International Conference on Indoor Air Quality and Climate,* August 20-24, 1984, Vol. 3, pp. 151-156

141.Sulman, F., "Absence of Harmful Effects of Protracted Negative Air Ionisation", *International Journal of Biometeorology,* Vol. 22, No. 1, 1978, pp. 53-58

142.Sulman, F., "The Effect of Air Ionization, Electric Fields, Atmospherics and Other Electrical Phenomena On Man and Animals", Charles C Thomas Publisher, Springfield, Illinois, 1978

143.Sulman, F., "Air-Ionometry of Hot, Dry Dessert Winds (Sharav) and Treatment with Air Ions of Weather-Sensitive Subjects", *International Journal of Biometeorology,* Vol. 18, No. 4, 1974, pp. 313-318

144.Sun, M.,"Ion Generators: Old Fad, New Fashion", *Science,* Vol. 210, Oct 1980, pp. 31-32

145.Swan, W., "Atmospheric Electricity and Ionization, *Proceedings of International Conference of Ionization of the Air,* Oct 16, 1961, Vol. 2, pg. XXIV-1 to XXIV-16

146.Tal, E., "Effect of Air ionization of Blood Serotonin in Vitro", *Experientia,* Vol. 32, No.1, Mar 15, 1976, pp. 326-327

147.Terman, M. and Terman J., "Treatment of Seasonal Affective Disorder with a High-Output Negative Ionizer", *The Journal of Alternative and Complementary Medicine,* Vol. 1, No. 1, 1995, pp. 87-92

148.Terman, M., *Personal Internet Communication*

149.Terry, R. and Harden, D., "Effects of Negative Air Ions, Noise, Sex, and Age on Maze Learning in Rats" *International Journal of Biometeorology,* Vol. 13, No. 39, 1969

150.Tom, G., "The Influence of Negative Air Ions on Human Performance and Mood", *Human Factors,* Vol. 23, No. 5, 1981, pp. 633-636

151.Tromp, S., "Biometeorology: The Impact of the Weather and Climate on Humans and Their Environment (Animals and Plants)", Heyden Publishing, London, 1980

152.Tromp, S., "Medical Biometeorology: Weather, Climate and the Living Organism", Elsevier Publishing Company, London,1963

153. US Department of Health and Human Services: The Consequences of Smoking: Cancer. A Report of the Surgeon General. Rockville, MD, Department of Health and Human Services, Public Health Service, Office of the Assistant Secretary for Health, Office on Smoking and Health, 1982

154.US Departments of Housing and Urban Development and Environmental Protection Agency, NTIS PB-290999, "Indoor Air Pollution in the Residential Environment", Vol. 1, Dec 1978, pp. 164-172

155.US Environmental Protection Agency, EPA 400/1-90/002, "Residential Air-Cleaning Devices", February 1990, pp. 3-19

156.Varga, A., "Research Report on the Physiological Effects of Air Ions and Their Significance as Environmental Factors", *NASA Tech Memorandum(*75086), Feb 1978

157.Wagner, C., "Relation Between Positive Small Air Ions, Weather Fronts and Pulmonary Function in Patients with Bronchial Asthma", *Annals of Allergy,* Vol. 51, Oct 1983, pp. 430-435

158. Wallach, C., "The Ion Controversy: A Scientific Appraisal", 3rd Edition, Belle Lumiere Publishing/Australian Edition, 1980

159. Warner, J., "Double Blind Trial of Ionisers in Children with Asthma Sensitive to the House Dust Mite", *Thorax,* Vol. 48, No. 4, Apr 1993, pp. 330-333

160. Wehner, A., "Special Review Electro-Aerosols, Air Ions and Physical Medicine", *American Journal of Physical Medicine,* Vol. 48, No. 3, pp. 119-149

161. Wehner, A., "Negatively Charged Aerosols", *Chest,* Vol. 60, No. 5, Nov 1971, pp. 468-471

162. Wehner, A.,"The Clinical, Scientific and Technical Development of ElectroAerosology", *Proceedings of International Conference of Ionization of the Air,* Oct 16-17, 1961, Vol. 2, pg. XV-1 to XV-23

163. Werner, A., "Special Review: Electro-Aerosal Therapy", *American Journal of Physical Medicine,* 41:68, 1962

164. Werner, A., "Special Review: Electro-Aerosol Therapy", *American Journal of Physical Medicine,* 41:24, 1962

165. Whitby, K., "The Decay of Unipolar Small Ions and Homogeneous Aerosols in Closed Spaces and Flow Systems", *Proceedings of International Conference of Ionization of the Air,* Oct 1961, Vol. 1, pg. VII-1 to VII-30

166. Winsor, T., "Biologic Effects of Ionized Air in Man", *American Journal of Physical Medicine,* Vol. 37, No. 2, Apr 1958, pp. 83-89

167. Wofford, J., "Negative Ionization: An Investigation of Behavioral Effects", *Journal of Experimental Psychology,* Vol. 71, No. 4, 1966, pp. 608-611

168. Worden, J., "Some Biological Effects of Air ionization" *Proceedings of International Conference of Ionization of the Air,* Oct 1961, Vol. 1, pg. XII-1 to XII-24

169. Wright, J., "Recuperation; Charged for Recovery", *Muscle and Fitness,* Oct 1993, pp. 59-60

170. Wright, J., "Negative Ions", *Muscle and Fitness,* Jan. 19 , pg.125

171. Yaglou, C., "Observations on a Group of Subjects Before, During and After Exposure to Ionized Air", *The Journal of Industrial Hygiene,* Vol. XV, No 5, Sep 1933, pp. 341-353

172. Yates, A., "Effect of Negative Air Ionization on Hyperactive and Autistic Children", *American Journal of Physical Medicine,* Vol. 66 No. 5, pp. 264-268

173. Yost, M., "Design and Construction of Cage Environments for Air Ion and Electric Field Research", *International Journal of Biometeorology,* Vol. 31, No. 2, 1987, pp. 109-125

174. Yost, M., *Personal Telephone and Internet Communication*

## VITA

Stephen McNeilly Kinne[redacted] the son of Charles Harvey Kinne and Jane[redacted] Kinne. After graduating from Cicero High School, New York, in 1974, he entered the State University of New York (SUNY) College of Environmental Science and Forestry, Syracuse, New York where he majored in zoology. He was married in 1977 to Ann Pietrantoni of Syracuse. He graduated in 1978, receiving his Bachelor of Science degree. He joined the United States Air Force and attended SUNY Upstate Medical College at Syracuse. He received the degree of Medical Doctor in 1982, and then completed a medical internship and family practice residency at USAF Regional Hospital Carswell, Carswell AFB, Texas. Two children, Carrie-Ann Autumne and Jeremy Paul were born[redacted] respectively. He graduated and became board certified in Family Practice in 1985. He served as a family physician at Malmstrom AFB, Montana (1985-87), earning his Flight Surgeon wings in 1987. He was stationed at RAF Alconbury, U.K. (1987-91) where he served as both Chief of Primary Care and later as Chief of the Medical Staff. He spent three years on staff at the Travis AFB Family Practice Residency Program (1991-94), after which he accepted the position of Chief of Flight Medicine, Travis AFB (1994-96). He is now in phase I of his (second) residency in Aerospace Medicine.

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